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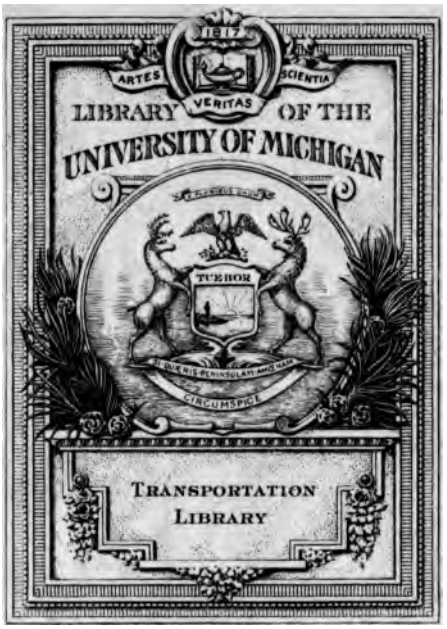
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ROAD PROGRESS;

OR,

AMALGAMATION OF RAILWAYS AND HIGHWAYS FOR AGRICULTURAL IMPROVEMENT,

AND

STEAM FARMING,

IN GREAT BRITAIN AND THE COLONIES.

ALSO

PRACTICAL ECONOMY

IN

FIXED PLANT AND ROLLING STOCK FOR PASSENGER AND GOODS TRAINS.

BY

WILLIAM BRIDGES ADAMS, ENGINEER,

OF FAIR FIELD WORKS, BOW; AUTHOR OF "ENGLISH PLEASURE CARRIAGES," THE "IRON WAYS," ETC. ETC.

"He would fain keep a hold on the Actual, knit the New securely to it, and give to them both conjointly a fresh direction." * * * "He recognises Motion as the true element of Humanity, and principle of the Universe."

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PREFACE.

THE writer of the following pages has been connected with the operations of Wheel Transit from his earliest years; and, at the advent of railways, voluntarily abandoned the largest existing private business, in order to keep pace with the new movement. From the commencement, he was aware of the vicious system of railway mechanism; but to attempt to stem it, while the whole aim of the public was how to multiply the number of the railways without regard to their efficiency, was utterly fruitless. Time has brought the cure; diminishing dividends have forced on the inquiry of dissatisfied shareholders into the causes of the diminution. They may be summed up generally under two heads, viz.:—

1. BAD LEGISLATION.
2. BAD MECHANISM.

Under the first head may be ranged legal and parliamentary expenses, excessive cost of land and compensation, and the choice of injudicious routes. Under the second part may be ranged the imperfect construction of the "permanent way" and substructure, the unmechanical structure of the locomotives and trains; and, in addition to these, the excessive weight of the locomotives and trains beyond what the rails were capable of sustaining,—and it may be added, beyond what it is practicable by human art to make them sustain, with an economic use of steam power.

The losses under the first head are irreparable, and must, sooner or later, be written off the account as wasted capital not

to be retrieved. The losses under the second head must also to a given extent be considered waste; but they are fortunately capable of retrieval in future by better mechanism; and in connexion with this better mechanism, railways are capable of almost indefinite extension, at one-third the previous cost, so as to be not only within the reach of every district and village, but also to make it worth while to open up lines through hitherto uninhabited districts, for the purpose of bringing into work both upper and under wastes—thus increasing vegetable produce and mineral wealth.

The writer, while recognising the truth that every sound practice must have a sound theory belonging to it, is yet well aware that theories must be crude till experience as well as experiment have jointly furnished sufficient data whereon to construct them. In examining the defects of railways, he has, with considerable outlay of capital, verified, both by experiment and experience, the new system he advocates of proportioning the means to the ends. That, as an inventor and practical manufacturer, he seeks to obtain a pecuniary recompense, by an extended business, will scarcely be urged as an objection to his propositions, unless the propositions themselves be unsound. That these propositions involve the supply of trains at less than half the former cost, to be worked at less than half the former cost, and without destruction of "permanent" way or annual outlay thereon, is an imperative reason why railway proprietors should examine them, both with reference to existing lines and to those yet to be constructed, which are by far the most numerous, notwithstanding the retardation of their progress by blunders and mistakes, inseparable from a time of great excitement, with the stimulus of supposed inordinate gain. But, sooner or later, the greater part of the highways must be converted into railways; and, in examining the maps, we find that there is still a large arrear of rails to be laid down. It may be true that in some cases hills offer difficulties, but they are mostly surmountable by levelling, *or by mechanical art* in the improved structure of engines.

ROAD PROGRESS.

DESTRUCTIVE WEIGHTS ON RAILWAYS.

When numerous steam locomotists first applied their energies to the common highways, they had two difficulties to contend with—the opposition of vested interests in horse-flesh, and the advent of the railways, whereon the hard iron surface obtained an enormous advantage. Had the road owners understood their own true interest, they would have levelled the roads, and laid down rails, and thus maintained their advantage. But the horse interest prevailed, and as a consequence they lost the race against the railways.

Astonished with the results obtained by the hard iron tracks in diminishing friction, the railway people began to believe that "weight was of no consequence in railways." They assumed as dogmas,—weight is speed—wear and tear is practically *nil*—rails will last thirty years—rolling stock an indefinite period—and so on. The errors since persisted in, were not wholly without warning. The writer's voice was lifted up against them, unregarded amidst the din of cupidity, that defeated its own proposed object—gain.

But *truth* will find it way. Rails have been destroyed, and rolling stock has been resolved into its original elements, and amidst this "wreck of matter" many human beings have been prematurely cut off, whose deaths are clearly traceable, in most instances, to disproportion of materials, as clearly as that deep ships will ground in shallow water, or eggs break under cart-wheels, or ice melt at 40° of thermometrical heat above zero.

The general principles that should govern the construction of railways in nowise differ from those of highways. They are both *roads* to bear rolling wheels, composed of a wearing surface and a substructure; in one case a surface of stone over the whole substructure, for the wheels to travel over all parts; in the

other case, a narrow surface of iron fixed to timber or stone blocks forming the substructure, the wheels being trammelled to run on the iron surface.

On the highway the strength of the surface and substructure is usually estimated by the load which horses are capable of drawing; but to prevent the crushing of the surface, the wheels are increased in breadth in proportion to the load; and to produce voluntary compliance with this essential condition, the tolls on highways are lessened in proportion to the increased breadth of the tyres or tread on the road. There are, of course, limits to this, and the usual practical limit, is, what four horses can draw. Even with that limited weight, it was found that the abrading surface beneath the wheels and the horses' feet was so serious an evil, by producing increased resistance, that hard iron rails with a narrow surface were substituted for the broad surface of yielding stone, and thus grew up the railway system.

But iron is not indefinitely hard, or substructure indefinitely durable; and these two facts were thoroughly appreciated by the Directors of the Liverpool and Manchester Railway when, in offering a premium for the best locomotive engine, they specified the maximum weight to be under five tons.

But they did not at the same time specify a maximum of speed, because, at that time, speed was not imagined. Even passengers were not imagined.

Running trains commenced, and passengers increased; carriage after carriage was added, for steam did not break its wind, did not die on the spot, as horses would have done. The result was, a lessened speed from increased load. But speed must be had at any cost, and the power and weight of the engines were increased. Again more carriages were added, and again were the engines increased. Then began the struggle for speed between the broad and the narrow gauge, till the rails and substructure gave way, and shareholders awakened to the conviction, that in six years they had worn out the fixed plant that was to have lasted thirty, and had also worn out—their dividends.

There is no doubt that speed is a useful thing, if it can be attained without too high a cost; and there is little doubt that speed may be maintained without excessive cost. But, to accomplish this, the managers of railways must take example from the practice of the highways. There, the fast coach was the light coach—heavy conveyances travelled slowly. On railways this practice has been reversed. The heavier the engine the faster the speed—as though weight and speed were synonymous, and not the contrary. The whole present system is confined in a *vicious circle*, from which there is no escape but by remodelling.

The rate of travelling must in all cases be more costly as excess of speed is attained; but we must not lose sight of the fact, that a light well-constructed train, with a specific number of passengers, can travel at forty miles per hour at less cost than a heavy badly-constructed train at twenty. And an engine of ten tons weight can attain as great speed as the largest engine that ever was constructed, and in most cases greater speed—precisely as the light Arab horse can outstrip the elephant, whose feet sink into the ground—precisely as rails sink beneath the tread of our monster engines.

To obtain the maximum of result on railways, it is essential, before all things, to ascertain the proportion of weight on the wheels of the rolling stock that the rails and substructure can sustain at the maximum speed, without crushing; for the heavier the load, the less in proportion must be the speed. It is quite true that the greater the speed, the less at intervals is the vertical weight while running, but so much greater is the impinging force laterally and longitudinally, and proportionably greater will be the amount of destruction.

It must be evident that all surplus weight in rolling stock is an unnecessary evil, carrying about lumber without profit; and the longer and heavier the train, the greater is the proportionate weight. The mere arrangement of springs to provide against longitudinal concussion amounts to half a ton per vehicle. The enormous disproportion of dead weight to load that has obtained on railways may be gathered from the facts, that the light stage-coach weighed seventeen cwt. and carried nineteen persons, including guard and driver, while the first-class carriage on a railway weighs four tons and carries eighteen passengers only. The risk of longitudinal collision caused by long heavy trains is the reason of this disproportion.

This surplus weight involves another difficulty. To start a train into motion requires many times the power needed to keep up speed when once attained, supposing the road to be level, and in good order. To check the momentum thus acquired, in case of an impending collision, or when stopping at a station, requires a corresponding amount of power, by using breaks, or by reversing the steam. All this is positive waste, and the more frequent the stoppings the greater must be the amount of waste.

There are two ways of considering the question of traction: mechanically and commercially. A thing may be mechanically practical which is commercially unadvisable.

Mechanically. First, the rails should be so hard as to resist abrasion on the surface in contact with the wheels; and so stiff, vertically and laterally, as to be incapable of deflection by weight.

or concussion of the passing load. And, moreover, the joints should be so formed that the rails at their abutment should be as free from deflection as at any portion of their mid-length, precisely as a fishing-rod is as strong at the ferule-joint as at any other portion.

Secondly. The substructure should be so firm, that no amount of rolling load can displace the sleepers, or crush them down so as to require "maintenance of way."

On scarcely any line of railway are these mechanical conditions to be found. The rails are abraded and crushed out on their surfaces; they are hammered into notches in their chairs, and are loose therein; and their abutting joints are not of one-fourth the strength to resist deflection that exists in their intermediate portions. The clinking, clattering sound familiar to the ear of every traveller, like the loose shoe of a horse, is caused by the springing of the rails in the joint-chairs at every fifteen feet distance, and not only destruction thence arises, but retardation of the train. The momentum is momently absorbed by concussion, and fresh steam must be generated to replace it: it is equivalent to starting the train afresh; and such bad joints are almost the only cause of engines and carriages getting off the rails.

It is evident, therefore, that the weight of the rolling stock is in excess of the railway strength. Mr. Stephenson warned the legislature of this three years back. "If you persist in the use of heavy engines, you must reconstruct your railways." The engine tyres are many times the strength of the rails they run on.

There are two mechanical modes of meeting the difficulty. One is, to increase the strength and weight of the rails and railway; the other, to diminish the weight of the rolling stock.

Against the former—increasing the weight of the rails, Mr. Brunel, who should be skilful in questions of weight, has lifted up his voice in the Institute of Civil Engineers, proclaiming that, in his practice, rails of 60 lbs. to the yard are more durable than those of 85. He says, that no good iron can be obtained in large sizes. Very possible, though that difficulty will not long endure under incessant competition, skill, and industry. The more probable solution is, that the light rail is elastic, and gives and takes better with the longitudinal sleeper to which it is fastened. And it is quite clear that the elastic yielding will have a tendency to elude abrasion. But this will be at the cost of wasted steam-power, precisely as a horse, in galloping over loose sand, will save the waste and wear of his shoes at a much greater expenditure of wind. The engine drives a wave of rail before it, as a steam-boat drives a wave of water.

The present rails of the heaviest make are 92 lbs. to the yard,

and practical instances exist of their being actually trodden out in nine months, by existing traffic. Therefore, to get a durable rail, the weight would require to be at least doubled, and the surface artificially hardened with steel, to resist abrasion. There is yet more than this. The contact of the wheel with the rail is a point, or, at most, a line, across the rail. The width of the present rails is two inches and a half. To get sufficient surface to prevent crushing, would require probably five inches breadth; and, to produce this, would require iron of at least 300 lbs. per yard.

To support such rails proportionably, would require a range of cross-sleepers in close contact with each other, similar to the "corduroy" roads of America.

This would be costly in capital; but supposing the traffic in proportion, warranting the incessant use of monster engines—a stream of passengers and goods not otherwise to be carried—it might be an advisable investment. The use of the monster engines, *without* the giant's road, can clearly only be ruinous.

But if, on examination, it appears that the amount of traffic could be carried over the same rails by merely duplicating or tripling the number of the trains, and thus reducing the weight, it would be commercially the best arrangement. And supposing the traffic still to increase, it would be better to duplicate the number of the rails than to duplicate their strength.

In dealing with vessels in water, increase of size is of little disadvantage compared with the advantage, because increase of size gives increase of surface-bearing. But the tread of a wheel on a rail can be very limitedly increased, and only by the breadth of the rail. Practically, the bearing surface is commonly a point.

To determine the weight that may be advantageously placed on a single wheel, we must revert to the power of iron to resist crushing. From the mechanical experiments of Tredgold, it appears that good wrought-iron begins to crush under a steady weight of eight tons to the square inch. Mr. Glynn, a later experimenter, gives us eleven tons, probably experimenting with an improved quality of iron.

Now, the driving-wheels of many locomotive engines have ten to thirteen tons on a surface of two points. It is evident, therefore, that destructive wear must ensue. Engines of thirteen tons weight on two points, at forty miles per hour, over unsteady rails, may very well warrant the appellation of *anti-dividenders*. If, therefore, the weight on a pair of driving-wheels can be reduced to five tons, the resisting power of the rails may be in excess of the crushing power of the load, and the way be rendered really "permanent," *i.e.*, permanent in durability and not in expense

of maintenance.* It is obvious that this is mechanically the most economical arrangement, if the mechanical power be competent to the commercial demand. Upon examination, we shall find that, in ordinary traffic, a large portion of the engine power is at present absorbed in carrying dead weight. An engine, a tender, a break-van, one first-class, and three second-class carriages, make up a gross weight of 55 tons on 30 wheels, and afford accommodation for 18 first-class and 96 second-class passengers—total 114.

Net weight of passengers, say	..	..	tons	9
Ditto train	..	..	..	55

or more than six tons dead weight to one ton of paying load.

But on the Eastern Counties and the Cork and Bandon lines it has been shown, that with a differently constructed engine and carriage, weighing only 21 tons, on 16 wheels, 20 first-class, and 96 second-class—total 116, may be conveyed at the same speed, and with a consumption of only one-third as much coke. In this case, the proportions will be

Net weight of passengers, say	..	..	tons	9
Ditto train	..	..	..	21

or little more than two tons dead weight to one ton of paying load. The advantages, therefore, in favour of the light system, are—

In non-paying weight, as	..	..	21	to	55
In passengers	..	..	116	„	114
In wheels ..	..	..	16	„	30
In coke ..	..	..	1	„	3
In oil and grease	..	..	1	„	3
In outlay of capital	..	..	1	„	2
Interest on ditto	..	..	1	„	2
Repairs ..	..	..	1	„	2
Depreciation	..	..	1	„	2
Maintenance of way ..	..	..	0	„	0

In answer to this statement, it may be objected that the large

* Odd things at times occur from the want of "harmony of parts" in the management of railways. On a certain occasion an engineer of rails took a fancy to lay down some of such a rounded section at the top, that the wheels had little more than a knife-edge to run on. "They will last four years," said the engineer of rails, "before they wear down to the flat." "What, in the meantime, will become of the tyres of the wheels running on knife-edges?" asked an innocent by-stander. "Oh, that's the business of the locomotive department," replied the man of metals. "What say *you* to that?" asked the by-stander of the locomotive chieftain. "Why, that I have better iron in my wheel tyres, and so I'll roll out the rails." He kept his word; but the profit to the shareholders may be imagined, while the two chieftains were thus "tarring on" wheel and rail, which should be "man and wife,"—"to *controversy.*"

engine has the capacity to take more carriages if required. But the light engine could take another carriage if required, or a horse-box or carriage-truck, as the boiler is far more powerful in proportion to size. But in this sort of indefinite calculation lies the great error committed by railway companies. They assume the largest possible, instead of the largest average maximum. The true plan is to provide for the maximum average, and let the occasional surplus wait till the next time, as was the case with the stage-coaches. A maximum average of 100, might on an occasion reach 1000, but it would be absurd to provide a train for them. The stage-coach proprietors put on a special for the emergency, and so should the railway proprietors. The expense may be objected to; but, in the first place, the expense should not be incurred without a remunerating number of passengers; and supposing the number sufficient, the only extra expense between two trains and one, other things being equal, are the wages of driver and stoker. But if a proprietor of an omnibus, with a maximum of 25 passengers, can afford a driver and conductor, surely it cannot be important with a maximum of 116,

Supposing that two small trains could be worked at the same cost as one large one, it is manifest that a greater profit would ensue by the increase of passengers, through better accommodation to the public.

In practice, on one of the most important metropolitan lines, the largest number of passengers in one train at one time, during twelve months, on the main line, was 230, and the average maximum 118. On the branches, the average maximum was 116. With light trains it would be practicable to run every quarter of an hour, as the risk of collision is very small; and special trains, with the expense so much reduced, would become more frequent. For branch lines, still smaller engines would suffice; and it is probable that it might be arranged for the guard to take the fares from passengers, without needing stations or clerks. In such case the existing stations might be let for refreshment-rooms, or for other purposes, at a profit rather than an expense to the companies.

If the various companies would adopt the practice of making up lists of the passengers entering and leaving the trains at every station, the numbers might be ascertained and accommodation provided accordingly. Supposing a train to consist of three first-class carriages, with 54 passengers, and nine second-class with 288—total 342, and that it was entirely full, the proportion of dead load to living would be 87 to 26. But nothing like this is the fact; for on one of the largest metropolitan lines, during the year 1847, the proportion of dead load to living was 26 to 1.

There are several mechanical questions to consider besides the mere lightening of the trains. The joints of the rails require to be made perfect, and the rails require better securing. Wheels and axles are yet far from having attained their true form, the whole system of breaks is a mechanical abortion, and springs are very imperfect. Twenty years have not sufficed to accomplish in railway plant what it took fifty years to accomplish in stage-coaches—the fixing a standard form. Yet it must be done before profits can be calculated on.

In making future railways—which will again be rife so soon as the final extent of wasted capital in the existing lines is understood—the light system must come largely into operation. The saving of cost in construction of bridges and works for light weights will be very great; and if landholders come to their senses, as they will be fain to do, the probability is that railways will be made, with rolling stock complete for passengers, at about £7,000 per mile of double way. The existing railways must look to it, and set their houses in order. They must write off their wasted capital, and make the most of their goodwill, being the first in the field.

In working out the question of lightness in rolling stock before alluded to, the plans of the writer were long kept in abeyance. The railways were sealed books, not to be opened save by the railway elect. Execute your contracts and hold your tongues was the practical law of the railway "Medes and Persians," to all workers in wood and metal. We are the law and the gospel. The blunders committed under this system were plentiful. Millwrights and mechanical engineers settled the question of running trains, and one result was, that the parts were proportioned from fixed machinery, taking into no account the blows and percussion. On one occasion, a builder of engines had an order given him by directors, who left him to his own discretion as to proportions. He consequently increased the rubbing surfaces of his axle-bearings considerably beyond the common practice and agreeably to experimental results. He was called in question by the then arbiter of standard forms, and gave his reasons. The arbiter overruled him; and strange to say, the same arbiter seven years after doubled the proportions he had before thought too large. This anecdote is given merely to illustrate the want of knowledge that prevailed amongst those in authority, with perhaps some indisposition to acknowledge it. In truth, engineers were so occupied with legislatorial and managing difficulties, that they had no time to pay attention to structure either of road or works, save of the most important portions, and still less time to give to the *consideration* of rolling stock.

An opportunity at length offered. The resident engineer of the Eastern Counties line deemed it an absurdity to put in motion thirty-five tons of metal, timber, fuel, and water, to convey himself and assistant at a heavy expense from place to place along the line, as a substitute for inconvenient trains that wasted three-fourths of his time waiting at stations. He therefore applied to the writer to construct a manumotive machine as light as possible, to be lifted off the rails to get out of the way of the trains. The machine was made, and a speed of eighteen miles per hour was attained; but, as might have been expected, driving a pair of six feet wheels by hand, and feeding the human fire with beef, instead of coke to the boiler furnace, was a step backwards into original human drudgery, not likely to be permanent in an age of progress. The next proposition was for a *bonâ fide* coke-eater on a small scale—a metallic pony, to travel fifteen miles per hour, and to weigh only five hundred weight, the said pony to be laid hands on, and carried off bodily, by four navvies, at the word of command.

This, too, was constructed, but the boiler was so minute that it would not keep up its heat. Disappointment was the result, and those who looked not beneath the surface, considered the matter extinct; but those who knew better, held on like an American "Bee."

> If 'twas no weel bobbit, weel bobbit, weel bobbit,
> If 'twas no weel bobbit, we'll bob it again.

With an enlarged boiler, new wheels, and a lengthened frame, but with the original axles of a pony-gig, $1\frac{3}{8}$ inch diameter, again was this small machine launched. It was then ascertained that she would "go;" but in passing "points" the axles were bent, and she was brought back to Fair Field Works to refit with new axles and connecting rods. The report had spread far and wide, and several engineers came to examine her. Some pronounced her a pretty toy; "but of course she will be of no use to work with." Others of deeper insight predicted, that "owing to her lightness it was impossible she could keep the rails." It certainly did occur to the writer, that in the latter case it would be very practicable to prevent her from "flying," by the application of paving stones or pig iron as ballast; but as the machine when ready, weighed twenty-three hundred weight, he considered the chances were against the "flying."

On the day of trial for the first time, this steam carriage performed a journey to Cambridge, with eight passengers, at twenty-five miles per hour.

The following is the general construction and performance.

The total length of the carriage is 12 feet 6 inches, including

machinery, water-tank, and seats for seven passengers, all on one frame, which is hung below the axles, and is carried on four wheels, 3 feet 4 inches diameter. The floor is within 9 inches of the level of the rails. It is propelled by two cylinders 3½ inches diameter and 6 inches stroke, acting on a cranked axle. The boiler is cylindrical, placed vertically, and is 1 foot 7 inches diameter, by 4 feet 3 inches high. It contains a fire-box, 16 inches diameter, by 14 inches high; with 35 tubes, 3 feet 3 inches long, by 1½ inches diameter; giving 5½ feet of heating surface in the fire-box, and 38 feet in the tubes. The water-tank is placed under the seat, and will contain 40 gallons.

Performances.—"From the weekly statement kept of the working of this engine, it appears that the number of miles run during the half-year ending 4th July, 1848, was 5,526; and the quantity of coke consumed was 7 tons 9 cwt, being at about the rate of 3 lbs. per mile. She has run altogether about 15,000 miles. The greatest speed atained on the level was 41 miles per hour. The ordinary speed that might be safely calculated upon for a long journey, was 25 miles per hour. She has performed the journey from London to Cambridge, a distance of 57½ miles, in 1¾ hours, being a rate of nearly 33 miles per hour, with a consumption of coke 2¾lbs. per mile."

Subsequently the carriage was christened the "Express;" and she went down to Birmingham to be experimented on. Before Mr. Samuel was aware, his engineering friends took him to the bottom of the Lickey Incline—one in thirty-seven—on the Birmingham and Gloucester Railway, and defied him to ascend it. Nothing daunted, he got up his steam, and turned the laugh by ascending the incline.

Those who were aware of the facts, began to think "there was something in the new system." But amongst the "heavy" opponents—some honestly and some interestedly—there were many scoffers. "How is your tea-kettle?" "Have you broken your toy?" was the common greeting. "How is your half-horse power?" Where is your travelling shaving-pot, propelled by the cigar?"

Nor is it matter of surprise that these things should be. In all things, vested interests are constantly growing up. The inventor or innovator of to-day has a tendency within him to become the conservative of tomorrow. He who has acquired fame and repute, and cash to boot, by building locomotives at £2,500 each, does not all at once comprehend that "twa deuks may be as gude as ae guse;" that twice £1,250 equals £2,500, and that the almost universal effect of reduced cost is increased *demand. But there* was another source of disinclination to the

progress of a light system. Large manufacturers, in their large capital and costly machinery enjoy a practical monopoly. To reduce size is to throw open the market. Nor may we be harshly critical on this propensity. Railway Companies who have largely wasted their means in trying to "hedge in the cuckoo" of monopoly, must not throw stones at the ironmasters and locomotists who wish to enjoy the monopoly of selling iron in large masses.

But there have also been many honorable exceptions from this kind of interested opposition. Some could at once see the advisability of applying the light-system to branch lines. Others, after thorough examination, hailed it as a means of paying "dividends." The earliest practical recogniser of the advantages offered by the light-system was Mr. Charles Hutton Gregory, who advised the Directors of the Bristol and Exeter broad-gauge line to order, for some of their branch traffic, a steam carriage for first-class and second-class passengers. This was built at Fair Field Works, and called the "Fair Field." The vertical boiler of the "Fair Field" was found to involve certain practical difficulties, though an exceedingly rapid and powerful steam generator, and was therefore replaced by a horizontal boiler.

The following are the particulars of the construction and the performance:—

"The 'Fair Field' steam-carriage was constructed for the purpose of working the Tiverton branch of the Bristol and Exeter Railway, broad gauge. It is an engine and carriage on one frame, the extreme length being 40 feet, hung on six wheels, the two front ones being drivers, 4 feet 6 inches diameter; the middle and trailing wheels are 3 feet 6 inches diameter. Extreme centres of wheels, 28 feet. It is propelled by 2 cylinders, 8 inches diameter and 12 inches stroke, acting on an independent cranked shaft, communicating by side rods to the driving wheels. The boiler was originally cylindrical, placed vertically, and was 6 feet in height by 3 feet diameter. The fire-box was 2 feet 6 inches diameter, with 150 tubes, 1⅛ inch diameter, with a heating fire-box surface of 20.6 feet, and 216 feet in the tubes. The tank is in front of the boiler, and will hold 240 gallons; it has since been fitted with a horizontal boiler, with a barrel 7 feet 7 inches long, by 2 feet 6 inches diameter. The fire-box is 2 feet 6 inches by 2 feet 3 inches, and 4 feet in height; with 115 tubes, 8 feet long and 1½ inch diameter. The heating surface in the fire-box is 37 feet, and 325 feet in the tubes.

"The body was divided into three compartments, one first class and two second class. Passengers, total number 58.

"*Performance.*—The Tiverton branch is five miles in length, and has a rising gradient of 1 in 86.

"The maximum load taken up this gradient was, exclusive of the carriage, 31 tons 13 cwt. 2 qrs. 16 lbs. in 11 minutes, being at the rate of over 27 miles per hour. Eighteen trips were run, being a distance of 90 miles, during a space of 9¼ hours, the running time being about 3¾ hours, and the standing time 5½. The consumption of coke per mile 14.8 lbs. Subsequently it was reduced to 13 lbs., and the engine now works with 8.7.

"The load consisted of two loaded wagons, each on four wheels of 4 feet diameter. The engine and carriages on 6 wheels, the whole train being on 14 wheels, while the engine and tender alone of the Great Western engines occupy 14 wheels without any carriages.

"The 'Fair Field,' ran a trip from Exeter to Bristol, 76 miles—with an extra load of 10 tons behind her, equivalent to 140 passengers total—in 3 hours 37 minutes; 58 being consumed in twelve stoppages, leaving the remaining time 2 hours 39 minutes, being a fraction under 28 miles per hour. The maximum speed attained in this trip was 47 miles per hour."

The maximum speed ultimately attained was 52 miles per hour.

Since writing the above, by the kindness of Mr. Rea, the Locomotive Superintendent of the Bristol and Exeter Railway, who has paid great attention to this question of railway economy, with a view to determine the saving to the Company by proportioning the power to the work done, the writer is enabled to furnish the following statement of results in every day work on the Clevedon branch of the above railway, on two following days.

"FAIR FIELD" STEAM CARRIAGE, CLEVEDON BRANCH, MARCH 26th, 1850:—

TRIPS FROM CLEVEDON TO YATTON.	Average Speed.	Miles per Hour.
1.	Clevedon to Yatton	24.0
2.	Ditto ditto	24.0
3.	Ditto ditto	26.8
4.	Ditto ditto	25.2
5.	Ditto ditto	26.4
6.	Ditto ditto	30.7
7.	Ditto ditto, 1 truck, 8 tons	21.5
8.	Ditto ditto	23.3

TRIPS FROM YATTON TO CLEVEDON.	Average Speed.	Miles per Hour.
1.	Yatton to Clevedon	24.7
2.	Ditto ditto, 1 carriage truck	25.0
3.	Ditto ditto, 1 wagon, 7 tons, 2 cwt. 3 qrs. 17 lbs.	23.6
4.	Yatton to Clevedon	26.4
5.	Ditto ditto	23.7
6.	Ditto ditto, 1 truck, 6 tons, 3 cwt. 0 qrs. 17 lbs.	24.4
7.	Yatton to Clevedon	22.9
8.	Ditto ditto	24.7

Total consumption of water running 16 trips, or 64 miles = 397½ gallons.

Total consumption of coke running 64 miles, including the time standing in steam—namely, 14½ hours = 5 cwt.

Consumption of coke per mile (560 lbs. by 64) = 8.7 lbs.

Actual evaporation of water, in lbs., to 1 lb. of coke (397½ × 10 = 3975 by 64) = 7.0 lbs. of water to 1 lb. of coke.

Cost per diem, without repairs :—

	£	s.	d.
Coke, 5 cwt., at 20s. 6d. per ton	£0	5	1½
Oil, locomotive, 1 pint, at 3s. 6d. per gallon	0	0	5¼
Engineman's wages, 6s.—fireman, 3s.—cleaner, 3s. per diem	0	12	0
Small stores, for cleaning, 1 lb. waste, at 2¼d. per lb.—½ pint oil, 2¼d.	0	0	4½
Firewood	0	0	4
Miles run, 64; Cost per mile, 3¼d. — Total per diem	£0	18	3¼

"FAIR FIELD" STEAM CARRIAGE, CLEVEDON BRANCH, MARCH 27th, 1850:—

CLEVEDON TO YATTON. *Average Speeds.*	Miles per Hour.	YATTON TO CLEVEDON. *Average Speeds.*	Miles per Hour.
1. Clevedon to Yatton	22·7	1. Yatton to Clevedon	22·5
2. Ditto ditto	23·7	2. Ditto ditto	25·3
3. Ditto ditto	28·6	3. Ditto ditto	24·9
4. Ditto ditto Load 1, Carriage Truck	24·2	4. Ditto ditto	25·9
5. Clevedon to Yatton	26·2	5. Ditto ditto	23·7
6. Ditto ditto	26·4	6. Ditto ditto 1 Truck, and 1 Wagon 8 Tons	18·8
7. Ditto ditto	25·9	7. Yatton to Clevedon	16·8
8. Ditto ditto	23·3		

Total consumption of water = 407½ gallons.

Total consumption of coke, running the 64 miles, including the time standing in steam—viz., 14½ hours = 5 cwt.

Consumption of coke per mile = 8.7 lbs.

Actual consumption of water, in lbs. to 1 lb. of coke (407½ × 10 = 4075 by 560) = 7.2 lbs. of water to 1 lb. of coke.

(Signed) MINARD C. REA.

April 1st, 1850.

Bearing in mind that this carriage has accommodation inside for 58 passengers, and that being within nine inches of the rails, it would be very practicable to carry an equal number on the roof without disturbing the centre of gravity, it yet becomes obvious that a very small traffic can be made to pay. But beyond this, thirty to forty tons gross load could, if required, be taken as a train, on the level, at 20 to 25 miles per hour, with small increase in the consumption of coke.

It appears, also, by Mr. Rea's statement, that the steam carriage was far from economically employed; for although she took occasional jobs of hauling wagons and trucks, she was in steam

daily fourteen and a half hours; and working only two hours and a half over 64 miles, at rather more than 24 miles per hour. If she had done a full day's work, the cost would of course have been reduced.

Nor is the expense calculated on a niggardly scale. Full wages, for driver, stoker, and cleaner, such as will induce them to use their engine well, and keep a permanent place, are allowed by Mr. Rea—which is true economy.

It appears, therefore, that exclusive of "maintenance of way," which under such light weights would be practically *nil*,—and repairs of the machine—upwards of 100 passengers can be carried over 64 miles for 18s. 3¼d.

And repairs on these light machines must be much less than those of the heavy engines, for their wearing surfaces are all proportionately larger, and the weight in motion is less.

Railway Companies cannot too highly appreciate the services of their engineers, who look into the future; and the writer gladly expresses the obligation he and his helpers have been under to Mr. Gregory and Mr. Rea, for their manly aid in enabling the thought of the brain to grow up into the work of the hand.—Heart, Brain, and Hand are the Trinity of Progress.

Bring the brain of the planner and the hand of the workman and the will of the director, into union, and there seems no reason why public works should not prosper.

After the "Fair Field" had made considerable progress, the Directors of the Eastern Counties Railway ordered of Messrs Adams, a steam-carriage called the "Enfield," the form, proportions, and performance of which were as follows:—as given by Mr Samuel, in a paper read by him at the Institution of Mechanical Engineers.

"The 'Enfield,' has 8-inch cylinders and 12-inch stroke driving wheels 5 feet diameter; distance between centres 20 feet width of framing 8 feet 6 inches. The boiler is of the ordinary locomotive construction, 5 feet long by 2 feet 6 inches diameter. The fire-box is 2 feet 10½ inches by 2 feet 6 inches.

"There are 115 tubes of 1½ inch diameter, and 5 feet 3 inches in length, giving a total of 230 feet heating surface in the tubes. The area of the fire-box is 25 feet, giving a total heating surface of 255 feet.

"The weight of this steam-carriage is 15 tons 7 cwt. in working trim. The engine and carriage being combined, it is evident that the weight on the driving wheels is increased by the load carried, and that this weight increases in the same ratio as the load required to be taken.

"The extreme distance between the centres of the leading and *trailing wheels* being 20 feet, accounts for the steadiness of this

machine; there is indeed no perceptible oscillation when travelling at the highest speed, and this verifies the observation 'that the steadiness of an engine depends not on the position of the driving wheel, but upon the length of the rectangle covered by the wheels.' This engine at the same time daily traverses curves of 5 or 6 chains radius.

"The 'Enfield' steam carriage was originally intended to convey 84 passengers; but as it was found that when she was put on as an express train the passengers increased in number, a 'North Woolwich' carriage was attached capable of conveying 116 passengers, and also a guard's break-van, making provision altogether for 150 passengers, which is now her regular train taken at a speed of 37 miles per hour.

"This engine commenced her regular work about eight months since, and the following return shows the miles run and coke consumed by this engine during the 7½ months regular working from January 29th to September 9th, 1849.

14,021	total miles run.
705	hours, running time.
1,457	ditto, standing time.
2,162	total hours in steam.
743	cwt. coke consumed in running.
408	cwt. ditto standing.
286	cwt. ditto getting up steam.
1,437	cwt. total coke consumed.
11·48	lbs. per mile average consumption of coke.

"The 'Enfield' is in steam 15 hours per day, the fire being lighted about six in the morning and drawn at ten o'clock at night. But of these 15 hours it appears, by the return, that she is engaged running only 5 hours, the remaining 10 being employed standing in the siding. It was found by experiment, that the quantity of coke consumed standing was 32 lbs. per hour; and after deducting this and the quantity consumed getting up steam, it will appear that the actual consumption of coke running is under 6 lbs. per mile.

"It must also be particularly borne in mind, that this consumption of coke includes the total goods and coal traffic on the branch, amounting to 1,410 tons; viz., 169 tons of goods and 1,241 tons of coal.

"The 'Enfield' steam carriage worked the 10 a.m. passenger

train from London to Ely on 14th June, a distance of 72 miles, taking behind her three of the ordinary carriages and two horse-boxes: she arrived at Ely eight minutes before time, and the total consumption of fuel, including the getting up steam, was found to be 8¾ lbs. per mile. The tubes of the boiler are only 5 feet 3 inches in length, and the economy of fuel is consequently scarcely at the maximum.

"Another engine on a similar plan to couple with a 40-feet carriage is now nearly ready, the tubes being 6 feet 6 inches long, from which is expected even more economical results.

"The result of the writer's experience is the conviction, that for express purposes, and for the larger portion of the branch traffic on railways, the light steam carriage is the best adapted and most economical machine, both as to first cost compared to the work done, and in working expenses.

"The repairs of the permanent way are also very much reduced, as may be easily imagined.

"On the Eastern Counties Railway an engine and tender of say 30 tons, a break van, a first-class carriage, and three third-class carriages, conveying say 120 passengers, make a total weight of 59 tons, and the consumption of coke, as has already been shown, is on the average 34 lbs. per mile. A steam carriage weighing only 17 tons will transport the same number of passengers at from 7 to 8 lbs. of coke per mile when the best proportions are attained."

The "Enfield" has been put to a variety of work. Her *début* was in the route from London to Enfield.

At this time, Mr. Nixon, the engineer of the Cork and Bandon Railway, who had succeeded to the difficult task of correcting a series of blunders committed by those in authority before him, having heard of the light system advocated by the writer, deemed that he saw in it the true mode of making railways remunerative to the shareholders. A full and clear statement was made to him, and he made an experimental trip to Cambridge with the "Enfield," to verify in practice the theory that had been stated. The result was that he immediately ordered two light engines and trains on the writer's plan.

Far and near there arose a boding croak amongst the "heavies" and their adherents, on the receipt of this intelligence. "*Great* are the locomotives of the elect," was the aphorism of those interested in selling masses of metal, and also of those whose feet were only adapted to tread on frequented paths. Utter failure was prognosticated, and men of less purpose than Mr. Nixon, and his Directors, might have been turned away from their object. If Mr. Nixon were right, then the makers of heavy engines were

wrong; and alas! very few are they who, "filling a mighty space in the world's eye," are great enough in mind to say, "Even I am not perfect." It was asserted that the heavy engines would work light loads with as small a consumption of coke as the light ones, while on emergencies they would take larger loads. Wagers were offered on this point, with the view of demonstrating by cash power, a mechanical fallacy.

The light engines on the Cork and Bandon line were of the following construction:—Eight-inch cylinders, 12 inches stroke, on four wheels; driving-wheels, 5 feet diameter; leading-wheels, 3 feet diameter; distance between wheel centres, 10 feet 6 inches; length of boiler-barrel, 9 feet 8 inches; diameter of barrel, 2 feet 4 inches; circular fire-box (90 tubes), $1\frac{5}{8}$ diameter; length of tubes, 10 feet. The two engines are christened by sonorous Gaelic names, corresponding, in plain Saxon, to "Running Fire" and "Whirlwind." The weight of these engines is $8\frac{1}{2}$ tons, empty. They carry the water and fuel on their own frame.

The heavy engine was of the usual kind, with a tender, the whole being on ten wheels, the cylinders being fourteen inches in diameter.

The following is the extract from the Engineer's Report, comparing the two classes of engines during five months' performance, from August 1st to December 31st, 1849:—He states that the locomotive engines and carrying stock are maintained in good working order, and that a six-wheel ordinary size passenger engine and tender, having 14 inch cylinders, was delivered from the makers and has been at work from the month of October last, the manufacture as well as the working of which, have given him great satisfaction, more particularly from its consumption of fuel being much less than has been known in engines of such dimensions.

"The passenger trains are conveyed by the 'light' or small engines, which continue to afford most satisfactory proof of their efficiency and economy in working the passenger traffic on your line.

"The trains frequently consist of the following stock, all fairly laden:—

"One large 1st and 2nd class carriage for 58 passengers.

"One 3rd class carriage for 40 passengers.

"One horse-box for 3 horses.

"One carriage truck.

"Such trains are conveyed between Bandon and Ballinhassig station in 20 minutes, being at the rate of 30 miles per hour, including stoppages. (Gradient $3\frac{1}{2}$ miles, 1 × 100; total distance 10 miles.)

"The daily consumption of coke for each of these engines has been most particularly registered by your able station-master at Bandon, Mr. Coghlan, from whose returns, I find the average quantity of Newcastle coke consumed per diem, as follows:—

	Cwt.	qrs.	lbs.
"Consumed in lighting engine, time occupied 2 hours.	2	0	16
"Consumed standing in steam, time occupied 8 hours.	2	1	17
"Consumed in running 60 miles, time occupied 2 hours	1	3	26
"Total daily consumption .. .. cwt.	6	2	3

Which is equivalent to 12$\frac{1}{8}$ lbs. per mile per day of 12 hours; but it will be seen that the running time is only 2 hours, during which the consumption is not more than 3$\frac{3}{4}$ lbs. per mile.

"The average daily consumption of the Company's ordinary-sized engine with the same work, is 22$\frac{1}{2}$ lbs. per mile per day, or nearly double that of the light engines; and the same difference also arises between the two classes of engines in the consumption of oil, grease, &c., so that an important saving has been effected in the working expenses, by the adoption of engines whose powers and dimensions are in proportion to the loads they are required to convey.

"I have also to notice, that on referring to the working expenses of your railway, as per balance sheet, ending 31st December last, I find the total expenditure for working the line for five months, is £621 18s. 6d., and which amount, if divided by the mileage, 9,780, of that period, will shew that the nett cost of working the traffic, inclusive of every expense except maintenance of way, has been 15$\frac{1}{4}$d. per mile per train, inclusive of the frequent use of engines for sundry special purposes; and by adding interest and depreciation on rolling stock, the cost per mile, per train, will be about 17d.

"From the above statement it will be manifest, that the working of your railway has been commenced on the most economical principles."

The size of train described above would be sufficient for the transport of 150 passengers instead of 98, supposing the horse-box and carriage-truck changed for passenger carriages. Adding 5$\frac{1}{2}$ cwt. of extra coke for running, and 2 cwt. for lighting an extra engine, with a second driver, stoker, and guard, 24 trains might be run per diem, instead of 6, at an increased expense of about 25s. per diem.

The present cost for six trains is 85s. per diem, or 17d. per mile for sixty miles, which covers every expense, save maintenance of way. Adding the increase would make up 100s. Divi-

ding this by the increased mileage 240 would give 5½d. per mile per train, or 4s. 7d. for the transit of 150 passengers over ten miles of line, or 3,600 passengers per diem at a cost of £5 10s.

But to keep working, a spare engine would be requisite, at a cost of 10s. extra per diem for interest, making up 6d. per train per mile, or £6 per diem, total.

It is obvious, therefore, that with a small addition to the stock, when the twenty miles of the Cork and Bandon line are completed, 1,800 passengers may be carried over the whole distance at a cost of £6 per diem, or 650,000 per annum for less than £2,100, including every charge except maintenance of way, which, when well laid and traversed by light engines, will be nearly *nil.*

Supposing the trains to be half full, at one shilling per head average, the annual amount would be £16,050, from which, deducting expenses £2,100, the net profit would be £14,150, or five per cent. on a capital of £283,000, or seven per cent. on the intended capital of £200,000, without parcels or goods traffic.

The number of passengers up to Christmas appears to have averaged about 160 per diem. The calculations made above are not on the supposition that such large numbers will be obtained, but merely to show at how small an outlay for stock, provision for transit can be made. But probably, when the line is opened throughout, the numbers will be trebled, or say 500 per diem. At 1s. 6d. per head, this number would leave a clear return of upwards of five per cent. on £200,000, being less than one penny per mile.

The speech of Major Beamish, the Chairman of the Cork and Bandon Company, at the half-yearly meeting, is here inserted, in order to shew how, by good guidance and energetic purpose, an apparently hopeless project—hopeless under the then existing system—was successfully carried through, and will probably be the forerunner of far more extensive operations.

"The doubts and difficulties which, although sometimes broken by gleams of hope, have, until a very recent period, encompassed our path, are now dispelled, and the completion of the line—as far as human agency can secure it—is now certain. (Hear, hear.) It may sound strange at a distance, or to those accustomed to the enormous cost of English railways, and the comparatively small sum requisite to effect the completion of our little line, that the mere fact of the means being now at hand for that purpose, should be made a matter for remark or exultation at a half-yearly meeting of the proprietors, in this the fifth year of our existence; but those who know the difficulties with which this undertaking was beset from its birth—the ricketty progress of its after years—the hydra-headed calumnies with which it was assailed—(Hear, hear)—

the enormous law and other expenses in which the Company were involved by the recklessness of their former engineer, who, whatever may be his demerits, has certainly the merit of having projected the line—(Hear)—the many things done which had to be undone—and the continuous refusals of the Government to afford us the smallest aid towards the completion of the railway until within the last six months,—will admit, that the present security for its completion is a "great fact," only to be exceeded by the actual completion itself. (Hear.) Gentlemen, when we look back to the proceedings of last February meeting, and the movement which preceded it, and call to mind the apprehensions which had either spontaneously arisen, or been sedulously impressed upon the minds of many of the shareholders with regard to the expediency of opening half the line, we find another cause for satisfaction and congratulation—(Hear, hear); and it is particularly gratifying to those of the Directors who, like myself, urged on this movement, and thus became, in a measure, responsible for its success—to find that not only has the opening and working of the half-line been completely successful *per se*, but that it has been mainly instrumental in bringing about those arrangements which have led to the contract for the completion of the line. (Hear, hear.) In fact, I believe that, without any exaggeration, it might be said, that if the ten miles from Bandon to Ballinhassig had not been opened and worked—if this portion of the line had not been found practically safe, admitting of high velocities—cheaply constructed and cheaply worked —readily taken advantage of by the public, and thus possessing all the elements of remunerative traffic—the eminent gentlemen with whom we have now the good fortune to be associated, would not only not have entered into the contract, but would not have entertained it. (Hear, hear.) But another most important consequence has resulted from this experiment. It has tested and proved, in a manner the most indisputable, the soundness of the principle of apportioning the power to the weight to be moved. This principle I endeavoured to explain to the shareholders at the last February meeting by reference to the work on 'Railway Economy,' then recently published by Professor Gordon, Regius Professor of Civil Engineering in the University of Glasgow, a gentleman whose scientific and practical knowledge constituted him a high authority. But now we are independent of all theories, and all extraneous practice; for the opening and working our own line has proved in a manner the most practical, the most continuous, the most convincing, and the most complete, the soundness of the principle enunciated by Professor Gordon, and first brought into active operation by the Messrs. Adams of the Fair Field Works. (Hear, hear.) The speed, safety, facility of stopping and starting; power of overcoming curves and gradients—those formidable curves and gradients which, at one time, so much alarmed the shareholders—(a laugh)—but are now passed insensibly by the most nervous of our female passengers—are well known to those who have travelled on the line, and to most of the shareholders present, but the saving of

fuel is not so apparent to the mere passing traveller. I confess that I had considerable misgivings upon this point—as well from the startling announcement that the same work could be done with one half the consumption of fuel, as from knowing the strong adverse opinion of one of the most eminent engineers in England on the subject; and I requested your efficient and accurate station-master at Bandon, Mr. Richard Coghlan, to provide me, from time to time, with returns of the consumption of fuel. Gentlemen, I am happy to inform you that these returns entirely correspond with the results given by Mr. Nixon in his Engineer's Report, and far exceed the anticipations of Professor Gordon, who estimates the saving in fuel at 50 per cent., and the saving in oil for lubrication and repairs at 40 per cent. You will observe that Mr. Nixon's statement shows our consumption of coke with the light engines to be 12 1-4 lbs. per mile. Now, I will read, from a paper which was laid before the Institution of Mechanical Engineers in Birmingham, in October last, the statement of the engineer of the Eastern Counties Railway (Mr. Samuel) as to the average consumption of coke with both the light and ordinary locomotives upon that line :—

"On examining the coke returns, it also appears that the main line engines consumed from 24¼ to 40½lbs. per mile, and the engines for working the branch lines consumed from 16½ to 35½lbs. per mile, varying of course with the size of the engine employed to do the work, the *smallest engines* invariably consuming the *smallest quantity of fuel for the same work done.* The average consumption of coke during the half-year ending 4th July, 1849, was 31½lbs. per mile for passenger-engines, and 47¾lbs. per mile for goods engines."

"These returns refer to a stock of 200 engines, and a length of line of about 310 miles."

"The difference in the consumption of coke, therefore, between our light passenger-engines and the light locomotives of the Eastern Counties Railway is as 12 1-4 to 31½—far exceeding the estimate of Professor Gordon, and I have no doubt that it may be taken on an average as about 1 to 3. And this, it is to be recollected, with a speed of thirty miles an hour including stoppages—equal to forty or fifty miles an hour between the stations. (Hear, hear.) The cost of "maintenance of way" will necessarily be reduced in like manner, from the diminished deflection and concussion from the passing load. The shareholders have, therefore, no reason to be dissatisfied with the opening of the half line, or the employment upon it of the light passenger-engines. (Hear.) The Cork and Bandon Company may indeed now claim the merit of having been the first to introduce and establish in Ireland the application of the principle of apportioning the power to the weight to be moved. But while claiming this merit for ourselves, we must not overlook the far greater merit due to the inventors and patentees—the Messrs. Adams of the Fair Field Works, whose name will always be identified with the practical application of a principle, which I firmly believe is calculated to prove the salvation of railway investments."

If the Earl of Bandon and the landed proprietors of the south resolve that this thing shall be done—if they be thoroughly imbued with the conviction that the term "road" is the synonyme of "civilization,"—that cheap transit is the converse of barbarism, very simple indeed is the process of making the south of Ireland the abode of *wealth*, in the higher sense of the term—the general *weal* of the community. How this may be done will be shown further on.

While the Cork and Bandon engines were in process of construction, the Directors of the Eastern Counties ordered a second light engine, called the "Cambridge."

No. 6. The "*Cambridge*," was constructed for the Eastern Counties Railway Company, and was intended to run express between London and Cambridge. The extreme length is 16 feet 9 inches, and it is hung on four wheels, of which the leading wheels are 3 feet diameter and the drivers 5 feet. Distance between centres of wheels 9 feet 6 inches. Propelled by two outside cylinders, 8 inches diameter and 12 inches stroke, acting directly on to the driving-wheels. The boiler is horizontal, with a barrel 2 feet 6 inches diameter. The driving axle is placed behind the fire-box, which is 2 feet 10½ inches by 2 feet 6 inches outside diameter. The inner fire-box is 3 feet 1 inch in height, and contains 26 feet of heating surface. The tubes are in number 115, 6 feet 9 inches long and 1½ inch in diameter, with a heating surface of 259 feet. The tank is under the boiler, and holds 240 gallons.

The "Cambridge" generally performs the distance between London and Norwich (126 miles) in about four hours, that is, a speed of 30 miles an hour.

The following are particulars of a Trip on Thursday, Nov. 1, 1849, *with 'Cambridge' Engine and Train, from Norwich to London.*

Distance from Station to Station.	——	Time of Arrival.	Time of Departure.	Time occupied running.	Speed between Stations.
Miles.		H. M. S.	H. M. S.	M. S.	
	Norwich.....	..	10 30 0	..	(*a*)
3	Prowse-bridge	..	10 32 30	2 30	18
1¼	Ditto station....	..	10 34 30	2 0	3·75
5½	Hethersett.....	..	10 46 30	12 0	27·50
4	Wymondham.....	10 51 30	10 55 0	5 0	48 (*b*)

Distance from Station to Station.	——	Time of Arrival.	Time of Departure.	Time occupied running.	Speed between Stations.
Miles.		H. M. S.	H. M. S.	M. S.	
2½	Spooner-row.....	..	11 1 0	6 0	25
3	Attleborough.....	..	11 6 0	5 0	36
3¾	Eccles-road	..	11 11 30	5 30	40·90
3⅛	Harling-road.....	..	11 16 0	4 30	41·33
7⅞	Thetford	11 27 30	11 34 30	11 30	41·08 (*c*)
7	Brandon	11 47 30	11 50 30	13 0	32·30 (*d*)
3¾	Lakenheath	..	11 58 30	8 0	28·12
			P.M.		
5¼	Mildenhall.....	..	12 7 15	8 45	36·70
7	Ely.....	12 18 45	12 22 0	11 30	36·55 (*e*)
14¾	Cambridge.....	12 51 0	1 3 5	29 0	30·51 (*e*)
10	Chesterford	1 25 0	1 26 30	21 55	27·3 (*e*)
4	Audley-end	..	1 37 0	10 30	22·85
6	Elsenham	..	1 48 0	11 0	32·72
5¼	Bishop Stortford ..	1 56 0	2 3 30	8 0	39·37 (*f*)
6	Harlow	..	2 14 30	11 0	32·72
4¼	Roydon.....	..	2 19 30	5 0	51
3	Broxbourne	..	2 23 30	4 0	45
4¼	Waltham	..	2 29 30	6 0	42·50
3	Ponder's-end.....	..	2 34 0	4 30	40
2¼	Water-lane	..	2 37 30	3 30	38·58
1¾	Tottenham	..	2 39 45	4 15	46·66
2	Lea-bridge	..	2 42 30	2 45	43·63
2	Stratford	2 46 30	4 49 30	4 0	30 (*g*)
1¼	Bow	..	2 53 30	4 0	18·75
2½	London.....	2 58 30	..	5 0	30
				3 47 40	33·20 (*h*)
				4 28 30	28·15 (*i*)*

Since that time the "Cambridge" has been tried at various kinds of work on the Eastern Counties lines. The hardest work has been the traffic on the North Woolwich branch. The distance from London to North Woolwich is 8¾ miles, a considerable portion being reverse curves and steep gradients. At one portion the curve is of three chains radius, one particular part giving a versed sine of 7½ inches in 30 feet, or two rails length, 1 in 48: the gradient being at that spot a rise of 1 in 89.

* Remarks.—(*a*) Train consisted of engine, 8-wheel N.W. carriage with tank, 6-wheel first-class carriage, and 4-wheel break van. (*b*) Took water. (*c*) Water. (*d*) Coke and water. (*e*) Water. (*f*) Coke and water. (*g*) Water. (*h*) Actual running. (*i*) Including stoppages.
Coke consumed, 11½ cwt. = 10·22 lbs. per mile.

Over this line the "Cambridge" has ordinarily worked an eight-wheeled carriage measuring 40 feet by 9 feet, with accommodation for 116 passengers, and also a luggage break van. On one occasion 180 passengers were brought up, additional carriages being put on for the purpose.

Subsequently to this, the contractors for the formation of the Holyhead Harbour having experienced great difficulty in the use of horses to draw the stone trucks along the lofty scaffold erected over the sea, owing to the horses taking fright, and sometimes leaping over and taking the trucks with them—an expensive mode of adding to the under-sea embankment—employed Messrs. Adams to construct a small scaffold engine to supply the place of the horses, warranted not to take fright, or obey any other volition than that of the driver. The following is the description of the engine, which was named the "Breakwater."

No. 7. The "Breakwater," was constructed for the Messrs. Rigby, for ballast purposes, and is a broad gauge engine; extreme length 13 feet, hung on four wheels, 3 feet 3 inches in diameter, and coupled together. Centres of wheels 7 feet. It is propelled by two cylinders, 8 inches diameter and 18 inches stroke, acting on a cranked axle. The boiler is horizontal, with a barrel 2 feet 3 inches in diameter. The driving axle is placed behind the fire-box, which is 2 feet 8 inches by 2 feet 2 inches outside measurement. The inner box is 3 feet 2 inches in height, and contains 23 feet of heating surface. The tubes are 62 in number, 5 feet 3 inches long and $1\frac{3}{4}$ inch in diameter, with a heating surface of 132 feet. The tank is beneath the boiler, and holds 210 gallons.

Since the delivery of the "Breakwater," three more of these light engines have been ordered, one for the Londonderry and Enniskillen, one for the Caledonian and Dumbartonshire, and one for the Glasgow and Edinburgh; and the chief apparent difficulty in the way of their extension, is the amount of the heavy existing rolling stock. Many who are aware of the advantages of the light system would be glad to exchange these heavy engines, and such propositions have been made to the writer; but unless a market can be found for them in application to river steamers of small size, there is no remedy save wearing them out at a disadvantage, or selling them at a loss.

The "Fair Field" and the two Cork and Bandon engines have a peculiarity of construction. The driving wheels are in front, the furnace being 4 feet 6 inches in diameter, and the two latter 5 feet. It had been a generally received opinion that it was dangerous to have a large wheel in front, but experience seems to prove the contrary. The Irish engines have been run both ways;

but with the driving wheel in front they are invariably steady, while with the small wheel in front they tend to jump. The mechanical reason why this should be, seems very clear,—with the driving wheel in front the whole machine is pulled or towed along; with the driving-wheel behind, the small front wheel is pushed or propelled. Thus a steam-boat, with the paddle-wheels far forward, is easy to steer, but with them far aft, yaws, and is unruly to the helm.

The Londonderry and Enniskillen engine will be as follows:—

No. 8. This engine is being constructed for the Londonderry and Enniskillen Railway Company—the Irish, or 5 feet 3 inch gauge. The extreme length is 19 feet. It is on four wheels placed at 10 feet 2 inches apart. The leading wheels are 3 feet in diameter, and the trailing wheels 5 feet. Propelled by two outside cylinders, 9 inches in diameter, and 15 inches stroke, acting directly on to the driving wheels. The boiler is horizontal, with a barrel 2 feet 6 inches in diameter. The external fire-box is 3 feet by 2 feet 5 inches, outside measurement. The inner fire-box is 4 feet in height, with 37.5 feet of heating surface. The tubes are 86 in number, $1\frac{3}{4}$ inches in diameter, and 10 feet 9 inches in length, with a heating surface of 380 feet. The tank is beneath the boiler, and will hold 350 gallons.

Having gone through the account of what has been done in lightening the dead weight of haulage power on railways, the writer will now state his views as to what should be done practically to reduce the dead weight to the minimum, as compared with the load, in trains as well as engines, and to increase the durability of the road and rolling-stock to the maximum.

As before stated, it is possible to construct a road sufficiently solid to sustain any weight that may be required; but there is the question of surface also to consider, and the capacity of iron to resist abrasion. A steam-boat may be indefinitely long and large, because the sustaining surface of the water increases in proportion. But the driving-wheels of engines stand each on a point or on a line—the impact of the circumference of a cone on a plane. Eight tons and eleven tons pressure per square inch, are by various authorities given as the limit at which wrought iron begins to crush. Now it is demonstrable that unless a rail bends beneath the driving-wheel of an engine, the usual contact is only a point, or a line, and with the pressure of six tons on a point it is clear that the iron must abrade. To set this matter at rest the writer has prepared experiments with an hydraulic press provided with a registering valve—a piece of rail being made to impinge on a hard steel surface, representing a portion of the tyre of a five feet driving wheel. The results will be published when attained.

It must therefore be clear that if it be desired to maintain durable rails, the weight in the driving-wheels must not reach the crushing limit.

But in answer to this, it may be contended that rails have for years been run on by weights heavier than this, without abrasion.

The reply to this is, that in all such cases the rails have been saved by their flexibility beneath the loads, and this has been at an enormous waste of steam power. The value of a road as a means of lessening draught consists in its hard and unyielding surface. If, for the sake of saving the road, it be made flexible, its value is proportionately lessened.* But a rigid road requires light and perfect rolling stock, and in practice it has been found necessary to take up stone sleepers and replace them by timber. The most remarkable proof in this case was in the construction of the Leeds and Manchester line, when the chains and rails were laid on the solid levelled rock without the intervention of sleepers. But a few weeks' experience were required ere the rails were removed and wood sleepers laid beneath them.

It may be urged that the simple mode of distributing the weight of an engine so as not unduly to load a single pair of wheels, is to couple them — using four or six driving-wheels instead of two.

For a four-wheeled engine at a slow pace for mineral traffic this may not be objectionable; but for great speeds it would induce abrasion, because it would be practically almost impossible to construct a road on which four wheels could run with correct peripheries, so as to preserve an equal tread on the rails. The result must be increased friction and consequent loss of available power. Six wheels would be still more mischievous.

In reference to the actual friction of heavy engines and trains, the enormous weight of the tyres now used on driving-wheels, and the constant re-turning in the lathes required, as they roll out sideways or into hollows, is too well known to dwell on. And as regards rails, practical examples exist of some 92 to the yard, and well bedded on timber, being rolled out in less than twelve months so as to become useless, and these rails were guaranteed by the manufacturers for two years.

Supposing that traffic be procurable in abundance, it is the obvious policy of a railway company to carry as heavy trains as

* Collateral evidence of this fact has been communicated to the writer by an eminent ship-builder, and proprietor of a "slip" or inclined plane for the purpose of hauling a vessel out of the water. His hauling power is equivalent to 2000 tons, but the rails are only laid for about 900 tons; but frequently a vessel of 1400 is hauled up on 160 wheels,—about nine tons per wheel. But this is only when the rails are perfectly regular, and in good order. When the *slightest* deflection occurs, the power is immediately limited to 300 tons by the *increased resistance*, and the machinery has been broken down by the strain.

may be practicable without destroying their road. These trains must depend upon the inclinations or gradients. But in all cases the power of iron to resist abrasion must be the limit they cannot profitably exceed. The adhesion of driving-wheels with a weight of four tons will be sufficient on a perfect line to draw 100 tons on a level, not taking into account the resisting force of violent winds, or slipping by frost, in which case the machine will require loading, to induce adhesion, just as a horse will pull a greater load up hill with a rider on his back than he can unmounted.

In making a railway, the first consideration is the level that can be obtained at a commercially available cost. If the country be hilly, rapid travelling will be costly, on account of the levelling. But with slow travelling, smaller driving wheels may be used, and thus the power may be obtained for ascending bad gradients. "Increase of speed is loss of power; increase of power is loss of speed," are the mechanical axioms to work by; and the steepest gradient of a line should be the datum from which to calculate the construction of the rolling stock, unless other mechanical means be resorted to in aid of the locomotive,—such as a stationary engine with rope or chain, or the descending train pulling up the rising train; or two diameters to the driving-wheel, with raised rails to increase the available power of the crank, or other similar contrivances.

The next question is that the line be thoroughly drained, for on this depends the economy of maintenance. Over the general level the ballast, or other material, must be in sufficient thickness to ensure a firm base.

On this ballast the sleepers must have so much bearing surface, that they will not crush or be displaced by the rolling loads. Therefore, the heavier the engines, the more solid must be the roads and rails. In this view light trains are most important in keeping down first cost, not merely in way, but in bridges.

The width of way is another important consideration—not as regards the gauge, for that may be regarded as practically settled arbitrarily, though an integral five feet would have been better than the fractional measurement adopted, on various accounts. But it is in all cases important to diminish the length of trains, which materially increases atmospheric resistance, and also friction on curves. The best mode of doing this is to increase the width of the carriages and engines. The writer has constructed numerous carriages, nine feet in width, or two feet wider than their ordinary stock, and six inches wider than broad-gauge stock; but the width he would have preferred, for many reasons, is ten feet, had not tunnels and bridges interfered with the arrangements. Very great economy in first cost of rolling stock, and also in working, would have been the result of this, very far more than

compensating for a slight additional outlay on the lines. Nor would any greater width of land have been required, as with light stock, the rails might be carried closer to the edges; and even now, in many districts, it would be practicable to make additional lines on the railway slopes, for light work.

In laying "permanent way," two forms of rail have been mostly used. One which is generally, though not always used with longitudinal sleepers, is fastened down to the sleepers with vertical screws or bolts passing through flanges, rolled on the edges of the rail. This rail is mostly used on the broad-gauge lines. It has the advantage of a broad bearing surface on the timber; but the form of the iron is badly adjusted to resist vertical deflection under the passing loads, the total vertical depth not exceeding 3½ to 4 inches. In practice it is found that the deflection causes the wood-screws to draw out and break; and therefore the modern practice is to screw the rails to the timbers by bolts and nuts. At the joints, broad plates of iron are laid beneath the rails, to prevent them pressing into the timber; but there is much expense involved in shifting the rails, when required. Yet there is no doubt that the trains run more smoothly over this kind of permanent way than on the cross-sleeper system of the narrow-gauge, which could scarcely have stood the work of the heavy Great Western trains.

The rails used on the narrow gauge are chiefly of the double T form. Their total depth vertically is from 5 to 6 inches. The section is a vertical web, with a top and bottom rib. To secure them in their places, cast-iron chairs are spiked or trenailed down to the cross sleepers. In these chairs the rails are laid, and are secured by wooden keys driven against them, pressing laterally between the chair and the rail. The ordinary chairs are 3½ inches in width. The joint chairs where the rails abut, are about 5 inches. The wood sleeper beneath the joint is also of large size. On some lines the cross sleepers are 5 feet apart; on others 3 feet 6 inches, on others 3 feet, on others 2 feet 6 inches, and the more numerous the sleepers the better is the road. The usual length of the rails is 15 feet; and when laid in winter, an opening of about one-eighth of an inch is left at the joints, to allow for expansion in summer.

The advantages alleged in favour of this kind of railway, are, the facility of laying down and replacing. The form of the rail also gives much greater resistance to vertical deflection, with the same amount of metal. And the drainage is usually considered more easy than with the longitudinal plan of timbers. But the disadvantages are considerable. A large portion of the cross sleepers is wasted, as it is found impracticable to use their central *portion for* bearing surface, as in that case they would rock under

the loads. Again, the bearing of the rails on the cast-iron chairs is so small, that the rail crushes and hammers out, and after a year or two of wear the chairs are sunk in their thickness from one-eighth to one-quarter of an inch, with a corresponding indentation in the rail. When this has taken place it becomes impossible to make the joints secure or solid; the rails are incessantly "tipping" downwards and working loose, and the wood-keys get out. This is almost always the cause of the accident when trains get off the line, and this is also a main cause of the expense in "maintenance of way," amounting in many cases to upwards of 300*l.* per mile, per annum, for labour, rails, sleepers, keys, chairs, and fastenings. The following is a return of the cost of a northern line which is but lightly worked.

MAIN LINE.

Rails per annum	£ 74
Sleepers	70
Wages	80
Points and crossings..	18
	£240

BRANCHES.

Rails per annum	£ 56
Sleepers	70
Wages	60
Points and crossings..	14
	£200

Impressed with these disadvantages, the writer, regarding rails and wheels in the light of "man and wife," sought a method of obviating their imperfections. The first question was the joints. His mode of dealing with this evil was as follows:—

Removing the chair and sleeper altogether from the joint, a pair of iron fishes, 18 inches long and 4 to 6 inches deep, were applied, one on each side the rail, bearing in the side channels. Four bolts pass through these fishes and rails, tightly screwed up, fitting in the holes of the fishes, but the holes in the rails being left large, to allow for expansion and contraction. The sleepers and chairs being applied to the rails at the extreme ends of the fishes, the whole is rendered firm and complete. The fishes would be better 2 feet 6 inches, or 3 feet in length.

Samples of this having been laid down on the Eastern Counties line for fifteen months, the result was so satisfactory that the Directors ordered a mile to be laid down between Stratford and Lea Bridge, on the northern and eastern division. For this

purpose rails were used that had been condemned, the ends having been destroyed in the chairs. It was of course impossible to make a fit of the rails at the outset; but being made fixtures one to the other, they soon became flat, and the drivers now regard this as the best portion of the whole line. The expense of "maintenance" on this portion is now a mere fraction of the former cost, and the expense of new rails has been saved. The keys do not get out, and thus much risk is avoided.

But still there remained the difficulty of the small bearing surface of the rails in the chairs, and consequent destruction of the rails. To obviate this, the writer devised a plan of dispensing with the keys and chairs altogether. Two pieces of timber, seven inches square, and thirteen feet long, were grooved out to receive the rail, imbedded to the upper lip. These pieces were bolted together beneath the rail, and held it as in a wooden vice, with a continuous bearing throughout the whole rail surface, where in contact with the wood.

It was at first supposed by many that the rail would press through the timber, so contrary was the plan to all received notions. But it was easily demonstrable that the bearing surface on the timber was greater than in the common plan; and as metal was not bedded upon metal, the result was general durability, though the sample was laid down on a line of the hardest work known—the Eastern Counties between Bow and Stratford.*

Thus a mode of constructing "permanent way" was achieved of a really *permanent* kind, fulfilling the following conditions, at an expense not greater than the relaying modes:—

1. By means of the fishes the rails were made to form a continuous line, yet free to expand and contract, removing all risk of bad joints, and preserving a level road, economising steam power, and removing concussion.

2. By being imbedded in timber, the power of the engine to unseat the rails is diminished.

3. The bearing surface of the rail in the timber, and the bearing surface of the timber on the ballast is increased.

4. It becomes practicable to preserve the lower surfaces of the rails in paint, to prevent rust.

5. Chairs and keys are dispensed with, and the number of parts lessened.

The depth of the rails should of course be of such amount as to prevent deflection by the passing load, and the width should be such as to prevent indentation or abrasion by the wheels.

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* The stable for the iron horses being four miles from the coaching office, it *follows that for* the greater part of the trains an empty engine must run twice *over the rails for one* trip of duty.

Whether the surfaces shall ultimately be steeled, or otherwise hardened, is a question for commercial consideration.

But there is yet another difficulty. Timber, bedded or partly bedded in moist earth or ballast, is very apt to rot. Creosoting and other chemical processes obviate this; but chemical durability is generally gained at the loss of mechanical strength. For this reason stone blocks were formerly considered "*permanent* way." But the impracticability of keeping cast iron chairs firm on stone blocks, led to attempts to use felt between, as an elastic medium. The best result would have been attained by using longitudinal wood sleepers between the rails and the stones. Impressed with this, the writer, many years back, in his work on "wheel carriages," proposed to bed longitudinal timber in a foundation of brick and cement, forming a groove for the timber in the brickwork. Of late it has been proposed to use cast iron, altogether dispensing with timber. The numerous experiments will solve the question of practicability; but, in the writer's judgment, the use of timber will be found an essential element of durability, in evading the effects of concussion. The ordinary wood wheel of the highway, shod with a hoop tyre, is probably the strongest existing mechanical construction, when viewed with regard to the work it performs; and in carriages generally, this construction of wood and iron is absolutely necessary to attain durability.

Mr. Samuel, resident engineer of the Eastern Counties Railway, has lately constructed a cast-iron sleeper, fulfilling some of the above conditions. A cast plate, 16 inches wide and 3 feet 6 inches long, is formed with a trough lengthwise down the centre, wedge-form, 4 inches wide above the top, and 3 inches at the bottom, and about 4½ inches deep. This trough is lined with two pieces of timber, filling up the length, and so grooved by a machine as to embrace the rail between them. Thus the rail only rises 1½ inches above the surface of the cast-iron, and no mischievous leverage takes place, as when chairs are used. The weight of the rail and load compresses the timber into the wedge form trough, and the rail thus lies in a close-fitting wooden cushion which cannot be crushed away. Three of these longitudinal sleepers are used to each rail length; and the end of the rail being connected by fishes, as before described, a very good permanent way is attained. The length of the fishes being 18 inches, and the sleepers 10 feet 6 inches, only 3 feet length of a 15 feet rail is left unsupported; whereas, by the present plan of chairs and cross-sleepers, only about 14 inches in 15 feet is supported on hard and badly fitting chairs. Openings are left at spaces in the cast-iron, so that moisture may get to the wood, and *prevent it from* unduly shrinking in hot weather.

On the South Eastern Railway, Mr. Barlow has tried to dispense with the wood sleepers altogether, by the use of cast-iron in large plates, with half-chairs cast in them, and then bolted together like the jaws of a vice beneath the rail, which the upper portions of the chairs clip between them. They are said to stand their work well, and there appears no reason why they should fail if they have sufficient bearing surface on the ballast, and they be thoroughly immoveable in their hold of the rail. The severest test will be at the joints, and experience seems to prove that in such positions wrought iron is needed to guard against fracture, or else the cast-iron must be used in very heavy masses. Out of these various arrangements will no doubt be produced the "best permanent way" that can be accomplished—really permanent. Whether the timber prepared chemically, or the cast-iron, will ultimately obtain the preference, is still a subject for experiment. But mechanically, the deep rail bedded in longitudinal timbers is the best structure that can be contrived.

For this cast-iron system, however, heavier rails would be required, the support not being continuous, like the timber-bedded plan before described. The cost of either plan would not exceed the well-constructed cross-sleeper mode, and would be greatly preferable. In districts where stone is cheap, a continuous wall of stone-sleepers, with a groove cut for the insertion of the timber and rails would be the best arrangement.

The next important question in laying out a railway, is so to arrange the stations, where practicable, that they may be always on a summit level, to facilitate starting from rest, and stopping with the minimum expenditure of steam-power and break-power.

The rails should in all cases form regular lines, whether straight or curved, so that there may be no abrupt angles at the joints. This is most important, and more especially at speeds. Defective points and crossings not properly curved into the line are a common cause of accidents, and always of wasteful wear.

The form of the rail surface on which the wheels are to run is important. It is a common practice to make it very convex, so that the wheels may run on a narrow edge. But the driving-wheels of the engines usually flatten the rails down in a short time. In this case, the coned form of the peripheries of the wheels induces great friction and wear, and resistance to traction even on straight lines, because of the different speeds at which portions of the tyres are travelling; pulling, as it were, in different directions. Some advantage may be gained in this way for the adhesion of the driving-wheels, but it is mischievous in all running-wheels. If the driving-wheels were cylindrical, and *the other wheels ran* loose on the axles, as hereafter described,

the difficulty would be removed. The proper form for the wheel tyres of an ordinary carriage on a highway, is that which they have a tendency to wear to in practice. The same principle should govern the form of rails—the form they have a tendency to wear to.

In setting out the trains to run on a railway so prepared, the first consideration is, that the weight on the driving-wheels should not exceed the capacity of the iron to resist abrasion or crushing. If more adhesion be required, the only mode is to couple together two pairs of wheels, which involves many mechanical disadvantages.

The point settled as to what should be the weight of the engine, which will of course depend on the strength and hardness of the rails, as well as substructure, the next question is, how best to construct the train that it shall offer the minimum of resistance from friction of the axles and wheels, and also from the resistance of the atmosphere and wind.

It would be desirable so to construct the engine that the centre of gravity might be at or below the level of the axles, because the machine would thereby be much steadier at high velocities. A disturbed pendulum has a constant tendency to return to a vertical line. A prop, on the contrary, has a tendency to fall to one side or the other with any disturbing force, such as the wheel-flanges striking the rails. But in a complex machine there are many intervening circumstances. It is necessary that all parts should be easily accessible and removable; and some of the undoubted advantages of a low centre of gravity must occasionally be sacrificed to obtain this facility. The reconciling these difficulties still offers a field for the ingenuity of the mechanist.

With regard to locomotive engines, a predilection has of late grown up in favour of "tank engines," *i. e.*, engines carrying their fuel and water on the same frame, on six wheels. Undoubtedly there is a convenience in getting rid of the weighty tender, and using six wheels instead of ten or twelve, but it can only apply to small engines for short distances. The tender was originally a contrivance to remove weight even from small engines. To increase their weight and load them with the water-tank, is a very wasteful contrivance. In several cases of late, existing engines have been thus treated, putting a huge tank on the back of the boiler—a sort of machine that has acquired the nickname of the "Elephant and Castle."

To make an engine run steady—*i. e.*, to make it safe while running, it must possess length. A six-wheel engine is apt to bind on curves. A four-wheel involves some risk if an axle breaks. To obviate this the writer devised a plan of a composite machine

on eight wheels, with a joint at the mid-length, permitting it to bend at curves. The fore part of this machine is the engine on four wheels; the hind part a carriage for the guard and his breaks—for luggage and letters—for fourteen passengers, and with a water-tank below—so that sixty miles may be run without stopping for water or fuel.

The advantage of this construction is, that while keeping the engine light, weight for adhesion can be thrown on the driving-wheels by the superincumbent weight of the carriage. And if an express train be required for a few passengers, the whole machine is complete in itself, and carriages may be attached as required. In this mode the break-van and tender commonly used, are merged in one vehicle combined with a passenger carriage—an obvious economy in weight and cost.

In the construction of train-carriages and wagons, the principle of four wheels is liable to several disadvantages. The centre of gravity being necessarily high for the convenience of passengers, and the base small, it is impracticable to employ really flexible springs, without involving such an amount of oscillation as to be unbearable to passengers and inconvenient for goods. The striking of the wheel-flanges against the rails while running, causes the body and load to impinge occasionally with three-fourths of the total weight on a single spring. The spring would be broken by the shock; and, to prevent this, the springs are made so strong, that they are practically not springs at all, save under violence. The amount of damage resulting to permanent way and stock from this imperfect four-wheel mode of construction, is very considerable. A short time back an American engineer visited Fair Field Works, and observing a number of four-wheeled wagons in process of construction, remarked—"What! do you make these foolish things still? We turned them off in the States long ago; they won't pay. We use no turn-tables—no man-handling of wagons; that eats up all the goods profits."

Mr. M'Connel, the Locomotive Superintendent of the London and North Western Railway, in a paper, read at the Institution of Mechanical Engineers, thus clearly describes the mischief:—

"The first strain to which the axle is subject is that rising from the weight of the wagon and load, which being received or resting on the journal produces the greatest effect upon the axle at the outer face of the wheel-boss, and to which is to be added the momentum of the load in falling through the spaces caused by *inequalities in the joints of the rails.*

"The injurious consequences upon the axle, of inequalities of the road surface, and flat places on the surface of the wheel-tyre, *by the jolting* or perpendicular motion which they produce, can-

not be accurately estimated, and these are very much increased when the bearing-springs of the wagon or carriage are not sufficiently elastic, and do not yield to the shock or blow downwards, so as (to use the expression) to cushion its effect. As an instance of the imperfect action of the springs, I would allude to those in use on many wagons, in which the form and construction cause them to be so rigid that the downward blow is more like a hammer upon an anvil. To obviate this strain as much as possible, it is necessary to proportion the spring so as to sustain the load properly, and yet to be of sufficient elasticity to absorb the effect of the load oscillation.

"The strain arising from the oscillation of the waggon on curves from imperfect coupling, and increased by the lateral freedom or space on the bearings or play between the rails and flanges of the wheels; when an irregularity occurs on the side of the rail or any sudden cause disturbs the direct motion of the wagon onwards, is in effect the same as a blow upon the flange of the wheel, the radius of the wheel tending to act as a lever to break the axle at the inner face of the boss of the wheel.

"This strain is in the compound ratio of the momentum of the load, the angle at which the wheel strikes the rail, and the distance from the centre of the axle to the point of impact, producing an effective strain upon the axle at the inner face of the wheel-boss, which extends proportionately over the whole axle between the wheels. To lessen in practice, as much as possible, the deteriorating effect of these descriptions of strains upon the axle, the following conditions are important:—

"That the bearings or journals of the axles fit as closely to the brasses as is consistent with freedom,—the allowance of flange-gauge of wheel being quite sufficient for the carriage to move freely round curves, and meet any irregularity in the gauge of the rails.

"That the wagons or carriages be as equally loaded as possible, and the draw-chains be exactly in the centre; and as side-chains are dangerous they should be completely removed, provision being made for a duplicate centre draw-chain should a failure take place. As the damage to the loading of wagons is in proportion to the oscillation, they should all be screwed together by means of screw-couplings, having spring-buffers upon both ends of every wagon.

"It is well known that the injury to the wagon, to the load which it conveys, to the axle which carries it, and to the road over which it runs, is very much aggravated if the waggons are allowed to oscillate from side to side to side, and become like so many battering rams, injuring themselves and all substances in contact with them. A train of wagons or carriages should be

jointed together similar to the vertebræ of an animal, by which means any sudden lateral action would be neutralised by the support derived from the neighbouring vehicles."

To obviate these difficulties without involving the inconveniences of the American plan of the eight-wheel "Bogy frame," the writer devised the double carriages on eight wheels, now used on the two sides of the river—the North Woolwich and North Kent lines, on the former of which they have been three years in use. The description of these carriages is as follows:

"These composite carriages of the North Kent line are formed of two four-wheel carriages bolted together, and are capable of separation when required, so as not to be unwieldy in case of removal, but constituting a rigid carriage when on the line. Their breadth is 9 feet and their length 40 feet, giving a total floor area of 360 square feet, or, as builders would say, upwards of three squares and a half.

"The advantages to the public of this mode of construction are, first, the possibility of using thoroughly flexible springs, with the utmost steadiness and freedom from oscillation, precisely as a long steamer preserves an even keel, while a short one pitches; secondly, greater safety; for, in case of collision, the long carriages will not leave the rail to ride on each other's backs, in which case the compressed buffers are discharged like cannon balls, breaking passengers' legs beneath the seats, as has more than once occurred in collisions; thirdly, eight wheels to one carriage are safer than four.

"The advantages to the shareholders are as follows:—

"First. These composite carriages cost the companies *only one-half* the price per passenger that the common stock costs. Secondly. The dead weight per passenger is *only one-half* that of the ordinary stock. Thirdly. The number of wheels are *eight* instead of *sixteen.*

"For these reasons, *cæteris paribus,* the engine power required ought to be considerably less, and the wear and tear of the road ought to be considerably reduced.

"The next question is of accommodation to passengers.

"The carriage is divided into four apartments, each having 90 feet of floor area. Externally they are all alike, being all fitted with plate-glass windows of larger size than any other carriages on any line, giving full view of the country. One of these apartments is furnished or trimmed with cloth and blinds, cushions, &c., and is arranged for twenty passengers seated. Now to compare this with an ordinary first-class carriage.

"The usual length is 16 feet 6 inches, the breadth 6 feet, and a proportion of the cubic contents is taken off by partitions, so *that we may* estimate this area in round numbers, say at 100

square feet: but the height is only about 5 feet 3 inches, making up 525 cubic feet; but the height of the long composites is upwards of 6 feet 6 inches, making up a total of 585 cubit feet, giving the same cubic measurement to each first-class passenger.

"The three second-class apartments are unfurnished; but as in all other particulars they are like the first, there is the manifest advantage of converting them to first-class when required; in fact, with a little arrangement, *the furniture might be made moveable*, to suit particular localities or seasons.

"Each of the second-class apartments is fitted for 32 passengers,—the precise number occupying a whole second-class of the ordinary stock, and with about the same cubic contents.

"Thus, these long carriages, by reason of their extra width and length, are capable of accommodating 116 passengers in a length of 40 feet of train, or 44 feet including buffers, moving with perfect steadiness, without the need of screw couplings to bind the train together.

"To carry the same number in the ordinary stock would require four carriages, measuring 84 feet in length. But we will state it yet more clearly:—

"Four long composites will convey 384 second-class and 80 first-class passengers, total 464, on 32 wheels, the length of train being 176 feet, and the number of doors 32.

"Twelve second-class and four first-class ordinary stock will convey 384 second-class and 72 first-class passengers, total 456, on 64 wheels, the length of train being 336 feet, and the number of doors 120.

"The mere extra length of platform, and extra number of servants required to open and close doors and grease wheels, is an important item in the daily work of a line of much traffic.

"The comparison is made with the ordinary four-wheeled stocks. But when it is compared with the six-wheel stock used on the Eastern Counties, North Staffordshire, Blackwall, and other lines, it will make a difference approaching towards a dividend.

"Thus, the savings of the new stock are:—

Wheels	32 : 64
Doors	32 : 120
Platforms	176 : 336
Dead weight	50 : 100
Servants	50 : 100

"This is exclusive of saving in traction and maintenance of way, which should be in the same proportion, if all things be rightly managed."

These carriages are suspended on bow springs, thoroughly

flexible, and composed of single plates of steel, the friction surfaces of which are confined to simple axis movements lubricated with oil, being thoroughly sensitive to the least movement, so that a carriage with its full load of 116 passengers may be swayed by the hand. The steel bows are sometimes used with a compressing action, and sometimes as elastic tension plates. Cross springs of the laminated kind are also occasionally used. By the lateral action of the springs, the wheels have a traverse of three to four inches to either side, so that these carriages with the extreme wheels thirty feet apart, will pass round curves of three chains radius, yet are perfectly steady at the highest velocities on the straight line.

These carriages are constructed of greater height as well as width than usual, permitting the tallest persons to stand upright; a great advantage for comfort on a long journey, and for surplus passengers on a short one, in an emergency.

A light engine, such as before described, would, with a consumption of 10 lbs. of coke per mile, take 250 passengers at a speed of forty miles per hour.

They have but two classes of passengers—first and second; but the first-class fares on the North Woolwich are less than the parliamentary scale of 1d. per mile—viz., 8¾ miles and the ferry across the river being only a charge of 8d.* Therefore, third-class passengers on this line would be simply additional dead weight without gain.

The resistance to traction of this kind of carriage must clearly be less than in the ordinary stock. Supposing the side were to be the same and the frontage the same, the openings between two carriages are avoided, which is so much frontage saved; and the flexible lateral traverse afforded by the springs, permits freedom of movement without grinding against the flanges. In case of a strong side wind, the bodies would yield laterally without carrying the wheels with them.

Had the railways been so constructed as to admit the passage over bridges and through tunnels of carriages ten feet wide, a very great advantage would have been gained, for the carriages might then have been constructed to permit the passage of the guard through the whole length of the train, and first-class compartments might have been fitted with every convenience, whether in isolated bodies for parties of two or four persons, or gregariously as saloons. The width of ten feet would have afforded two feet for passenger-way, and four feet on each side laid out as private apartments. And the carriages might have been thoroughly warmed and ventilated, and provided with numerous conveniences, in many cases absolutely essential for long journeys, when great

* Now reduced to 6d.

speed is required without stoppages. The passages through the second-class carriages would not be required, supposing them all open throughout, *i. e.*, without partitions, which would be a great advantage in economising space, and would in no way be objectionable, if the ventilation was arranged in the roof. In such case, the guard could at all times pass through the whole train, as in case of accident to communicate with the driver, or in case of accident to the driver, or in case of a drunken passenger annoying others, or of a madman, or accident by fire, or illness.

Supposing the tunnels of the broad gauge were sufficiently wide, it would be practicable to run thereon carriages on 12 wheels, 12 feet wide and 60 feet long, or 720 floor area, being accommodation for nearly 230 passengers. Such a carriage would run with the most perfect steadiness, and might be constructed to weigh little more than the ordinary tender, say 15 to 18 tons. It would consist of 3 four-wheel carriages, rigidly coupled together, with ample lateral traverse to the wheels.

The common objection made to the use of such large carriages is, that they are inconvenient to add to the train when there are only a few extra passengers, and are therefore lumber. But the answer to this is, that at present the trains consist of three or four carriages, whether full or not, and that by the use of the larger carriage, dead weight is saved in wheels, axles, and machinery of various kinds. It is easy to have small carriages to add if required; but it is not economical to construct the staple or main train in small separate carriages, increasing the number of the wheels needlessly.

It is probable that ultimately only two classes of carriages will be used on railways—first and second—and at moderate prices, graduated by the cubic space occupied by each passenger. The multiplication of classes multiplies the disproportion of dead weight. Many first-class passengers do not care for the accommodation, but for the company. With moderate prices and no third-class, the first-class would be filled instead of running empty. The poorer and rougher of the passengers would occupy the second-class, and gentlemen wishing seclusion, could with moderate fares, take a whole compartment. This arrangement would save the companies much surplus stock.*

The same principle which is good in carriages will also hold good in wagons. If two four-wheeled wagons are fitted to carry five tons each, the same wagons rigidly coupled together

* An objection has been sometimes raised, that station platforms do not permit the use of carriages nine feet wide. This is futile. On the Eastern Counties Railway and the North Kent lines they are in constant use; and, in most cases, cutting a few inches off the edges of platform floors would be paid by the saving in first cost of a single train.

would carry sixteen tons, and without oscillation. For cattle and sheep, and their safe transit, the advantage would be very great, by reason of their steadiness.

It may be objected that the long wagons could not be used with the common goods arrangements and storehouses. This may be so in some cases, though not in all, but the loss by porterage and labourers, and time in shifting and turning short wagons, is a serious drawback on the profits. The amount of mere buffer weight—the precaution against longitudinal concussion—saved by this arrangement, would amount to half-a-ton per carriage or wagon.

The advantages of flexible springs, yielding in all directions, have been already dwelt on, as permitting free action to the wheels. But the wheels themselves require much consideration.

Railway wheels, as usually constructed, are not properly wheels, but rollers, being fixed firmly each pair on a single shaft made to revolve with them. If the wheels thus fixed were exactly of the same diameter, it is obvious that they would have a tendency always to run forward in a right line; if of unequal diameters, they would have a tendency always to run in a circle of greater or lesser radius. But a railway is not a straight line, and the curves run both to left and right. Therefore, to suit these circumstances, each wheel is made conical on the periphery, the larger diameter internal and the smaller external—thus constituting a double cone. The wheels, therefore, will have a tendency to run either to right or left according as the rails curve; the larger diameter compensates for the increased length of the outer rail, and the smaller diameter for the diminished length of the inner rail.

But inasmuch as the bearing, or axle-boxes, in which the axles run, are secured in iron forks or guides resembling the rowlocks of a boat, and which only permit vertical movement, the wheels can only move laterally to meet the curves of the road by taking with them the carriage or load. The carriages are four-wheeled, and the rails are practically irregular, forming not merely curves, but small curves and angles, and indentations. The wheels incessantly strive to adapt themselves to this irregularity, and frequently one end of the carriage is borne to the right, and the other to the left, thus tending to produce the oscillation so unpleasant to passengers, which is aggravated by the alternate resistance and yielding of the spring-buffers between the carriages, or as a pugilist would say, "blows right and left." To impede this oscillation, the practice obtained of coupling up the whole train tightly together. This was practically trying to *force the* wheels to sledge or slide, and counteract the provision *for their rolling.* The result was, great wear of the brasses

or bearings by the operation of the mechanical law. As speed increased, the friction increased, and trains also increased in length, till the engines were overpowered; and then arose the outcry for more powerful engines, which in the contest for broad and narrow-gauge supremacy in speed, grew also in weight, till the rails sunk under them—crushed and destroyed.

The oscillation of the badly constructed four-wheel carriages caused many attempts to get relief by improved springs. But it was found that the more perfect and flexible the spring, the greater was the oscillation. Then six-wheel carriages were introduced, which induced greater steadiness, in partially counteracting the effect of a too high centre of gravity. But if the friction against the peripheries of the wheels be mischievous with a four-wheel carriage, it is clear that the six-wheel must materially increase it. It is an impossibility for a six-wheel carriage, as ordinarily constructed, to pass round a curve without sledging, and they are practically found to require a larger proportion of engine-power. The action is similar to a river stream which, at three or four miles per hour, flows easily through tortuous channels and round jutting promontories, but which, at ten or twelve, or greater speed, rushes against all obstacles, seeking to make for itself a straight channel.

It is evident that the use of a wheel is to roll, as the use of a sledge is to slide. Therefore every impediment to the rolling movement, whether on a straight line or a curve, or on a series of irregularities, should be removed. The fixed wheels can only roll by getting free lateral movement; but in many cases this lateral movement can only take place at slow rates of speed. At high speeds there is not time for the lateral movement, so rectilinear sledging is substituted for curvilinear rolling.

Carriages on highways have their wheels revolving independently round their axles. By this means, free movement, either rectilinear or curvilinear, is obtained. This is the plan that must sooner or later be adopted on railways.

It has been stated that this experiment has been tried and not found to answer in practice. The writer has only heard of two cases in which it was tried, and neither of these cases were calculated to answer. The experiment was simply boring out a soft cast iron nave, of insufficient length, and allowing it to revolve on a soft axle. The results in two cases—one on the broad gauge, and one on the narrow—were, that in two or three weeks they were irregular, and became eccentric.

The answer to this is, that had the same faulty work been applied to an omnibus, it would not have lasted two days, and were loose wheels and axles for railways made as accurately and perfectly

as the corresponding parts of an omnibus, they would last twenty years. The rolling movement obtained, the sledging wear would be stopped, and the tyres might be made much lighter. The worst part of the wheel in which to increase the weight, is the periphery, and on account of the great wear arising from faulty construction the weight is far too great.

With wheels revolving on their axles, and constructed without open spokes, which involve a mischievous fanning action, a tyre of one inch in thickness, and externally steeled or case-hardened, would be sufficient. At present wheel-tyres vary from one inch and a half, to two inches and a half, in thickness.

The wheels constructed by the writer are so arranged that the tyres are fastened laterally, without piercing the tread with bolt-holes. In this mode there is no risk of the tyre flying off at speed, an occurrence not uncommon where holes are pierced so as to weaken it.

But the loose wheels revolving on their axles would be open to a serious objection were they arranged precisely as the wheels of highway carriages. If the wheel of a highway carriage fires or heats, the friction stops the horse. On a railway this would be perilous. Therefore to guard against any chance of this, the axle is made to revolve in the boxes as usual, and the wheels are made to revolve on the axle. In practice, the axle will revolve in the journals continuously, and the movement of the wheels on the axle will be just so much as to provide compensation for the irregular and unequal rails they travel over. The first cost of such wheels and axles will be something greater than the ordinary rollers, but they will be durable through a long period of years.

The crystallization and breakage of axles is mainly owing to the imperfect practice of keying them fast on to a shaft, which involves enormous tension and other strains. With loose wheels axles of two-thirds the strength that are at present used would suffice, and the jar to the carriages would be lessened. The use of solid wood centres in lieu of iron spokes, and pressed into cold tyres instead of the mischievous practice of shrinking or hot, is also an important element in the manufacture.

It must be obvious that the lighter the train is, and the less the friction, the less will be the power required to start it into motion, and to keep up that motion when acquired. Were heavy goods trains of wagons coupled forcibly together, it would be impossible to start them. To facilitate this, each wagon is loosely coupled to the next, by a draw-chain. On some lines, the wagons are not provided with elastic traction or buffing springs. The first operation the engine-driver resorts to, is to back the whole train *of wagons* close to each other. He then puts his engine in

motion and snatches at the first wagon, which yields with a jerk till it tightens on the next, and so by a succession of jerks the whole are started. But in running, the wagons are constantly advancing to and receding from the engine, so that occasionally the whole strain of the train is on a single waggon. It frequently happens then that the chains break, and to guard against this, safety-chains are provided, one on each side; but the result of this is that on curves the chains pull only by one side, and various kinds of irregular action are involved, tending to breakage. When good traction-springs are used, this evil is mitigated.

The lighter the train also, the easier may it be stopped, or its speed checked, with a less amount of break-power, the more especially if the stopping-place be on an elevation. But the breaks commonly used are of the most mischievous kind, both with regard to the durability of the wheels and rails. Timber blocks of poplar wood are made to bear hard on the peripheries of the wheels, so as to stop their revolution. The result is, the grinding of many flat places on the tyres of the wheels, and the abrasion of the rails on which they sledge, driving them forward in the chairs as the wheels impinge on the yielding joints. When the wheels again revolve, these flat places, when at speed, strike the rails like so many sledge-hammers. The wheels then have to be taken out from under the vehicles and put into a turning lathe to reduce the tyre, and restore its circular form.

To obviate this mischievous result, breaks have been devised called rail-breaks, but which have not been brought into operation save as an experiment. One class is a long bar turned up at each end and made to bear upon the rails like a skate, the action of a screw forcing the whole weight of the carriage and axles to press on it, so that the wheels cease to carry the load, which is transferred to the sledge—the length of which occupies the whole distance between the wheels.

Another variety of this break is made to press upon the rail beneath the wheel-tyre. It is, in fact, the drag-shoe of the highways, better constructed and with better mechanism to apply it. The essential thing in either mode is to obtain as large a bearing surface as possible, both to make the breaks last as long as possible, and to increase the durability of the rails; and moreover, greater friction is attained, for though it is mechanically true that a given weight pressing on a given support will give out the same friction whether the rubbing surfaces be large or small—another element comes in on the rail, viz., the dirt and sand, so that friction increases with the amount of surface. Therefore, the larger the bearing surface the greater is the economy.

The only remaining consideration connected with wheels and axles is the question of lubrication. Locomotive axles and moving parts are usually lubricated with oil by means of a syphon wick. But the axles of railway carriages and wagons are usually lubricated with a species of soft soap composed of palm oil and alkali. This mixture is placed in a kind of hopper above the axle, with two small holes communicating through the bearings to the axle journal. As the axle revolves, the soap descends, and runs away at the open side below. It is obvious, that unless the opening be stopped, the soap will run rapidly away, like the grist from a mill.

But there is another objection to the soapy mixture. In summer time it is too fluid, and in winter it is apt to freeze, so that it is difficult to start a train that has been long standing.

To obviate these difficulties the writer has constructed an axle-box, now long in use, in which the lower part is made tight, and the opening between the axle and the box is fitted with an elastic stuffing, so that the soap or grease cannot escape. In this mode the upper part of the axle is lubricated in the usual manner, and as the grease escapes, it fills the lower part of the box and bathes the under side of the axle, which is thus immersed in lubricating fluid. The soap thus used after some time becomes slightly waxy, fitting the axle closely. A small portion of oil is then put in, and the axle runs in oil both above and below.

The economy arising from this arrangement is very great. The axles are not liable to get damaged nor the bearings to wear out, nor do the wheels require the expensive process of lifting; and at the same time a considerable quantity of the lubricating material is saved, while the risk of accidents arising from hot bearings is entirely obviated.

In considering the construction of trains for railways, the object must be taken into account. Light trains, full, are obviously better than heavy trains half full. An engine of ten tons weight, with, say, six tons on the driving-wheels, would take an improved train, with 250 passengers, at forty miles per hour. The same engine would take half the number at from fifty to fifty-five miles per hour. With an increase in the height of the driving-wheels, sixty miles might be attained, with sixty-four first class passengers, twelve servants, and luggage, and all this without damaging the line, the weights being within the crushing point.

But it is argued that there are certain trains to which people crowd at particular hours, and they must be taken. The reply to this is, that the first consideration is practicability; and if the number of people cannot be taken without a weight of engine and train damaging to the road, they must be divided, and two trains

started a quarter of an hour behind each other. "What!" the objectors will say, "think of the extra expense of guards, and stokers, and drivers."

More guards will not be more needed; for if there be two guards to a long train, one will suffice for the short one. Drivers and stokers will be extra, but the whole train will be lighter, and the consumption of coke proportionately less. Beyond this, there would be the saving in "maintenance of way," outweighing all other considerations. A saving of £200 per mile would, in a fifty-mile line, pay five per cent. interest on £200,000.

There is no truth more certain than that the engine which does not deflect the rails can usefully develope the whole of its steam power, while the engine which does deflect the rails must waste steam power, for it is always travelling up hill. The power is in excess of the fulcrum on the rails—just as a large horse flounders in a bog, over which a small pony may pass easily.

And with regard to the transit of goods, the same principle holds good—the road must not be crushed. A ten ton engine will take eighty tons gross on the level at fifteen miles per hour, and there does not appear any sufficient reason why goods should not be sent off as soon as sufficient are collected to freight a small train. Goods, no more than persons, are the better for detention; and in all cases it must be remembered that the smaller the trains the smaller is the staff of servants required at the stations and platforms. It is simply a question of employing fully a small number during a whole day, instead of a large number at distant intervals.*

The following is furnished by Mr. Samuel, of the Eastern Counties Railway, as the comparative consumption of coke per mile between the "Cambridge" light engine, with 8-inch cylinders, and an ordinary *light* engine of the Eastern Counties, No. 33.

No. 33 Engine.

"Average gross load as follows:—

Engine and tender	30½ tons

Cambridge Engine.

Engine	9 tons 12 cwt.
Tank under carriage to run long distance	2 „ 0 „

No. 33 Engine.

Total consumption for 7 trips, 910 miles .. 18,592 lbs.

"Deduct for standing at Cambridge 4½ hours per day for 3 days—13½ hours—at 80 lbs per hour, 1,080 lbs.; leaving net consumption 17,512 lbs., or 19.24 lbs. per mile. Average weight of train 35½ tons, or ·542 lbs. per ton per mile.

* See page 76.

CAMBRIDGE ENGINE.

"Total consumption for 6 trips—780 miles .. 9,868 lbs. Deduct for standing at Cambridge 1¾ cwt. per day for three days, 588 lbs., leaving net consumption 9,280 lbs., or 11.9 per mile. Average weight of train, 22 tons 11 cwt., or 505 lbs. per ton per mile.

December 31, 1849.

It appears clear, therefore, that the small engines are proportionately more economic in coke per ton than the larger ones, exclusive of the saving on the total amount consumed, and in the maintenance of way. The Cork and Bandon engines, which have the same sized cylinders, have larger boilers, and are proportionately more economical in coke.

The following is extracted from a paper read before the Institute of Mechanical Engineers at Birmingham, in October, 1849, on the general amount of passengers, and the applicability of light trains to convey them, by Mr. Samuel.

ON THE ECONOMY OF RAILWAY TRANSIT.

"The object of the present paper is to show that the locomotives now in use on most of the railways have outgrown the wants of the passenger traffic, and that the weight on the driving-wheels of these locomotives, amounting in some cases to 14 tons, is perfectly unnecessary for the number of passengers conveyed in 99 cases out of 100.

"For the purpose of obtaining practical data upon this subject, the writer of the present paper procured a return of the number of passengers conveyed on the Eastern Counties and Norfolk Railways, both main line and branches, by each train during the week ending 7th May, 1849; this return showing the greatest number of passengers in each train at any one time.

"It appears from this return that the greatest number of passengers in any main line train at any one time was 231, and the least number 7; the greatest number in any of the branch line trains being 82, and the least number 3.

"And by another return from the books of the company it appears that there were conveyed on the Eastern Counties' branch lines during the year 1847, 42,644 tons of passengers (calculating each passenger with his luggage at 168 lbs.), and the weight of engines and carriages required to convey them was about 1,112,500 tons, being in the proportion of 26 to 1.

"On examining the coke returns, it also appears that the main line engines consumed from 24½ to 40½ lbs. per mile, and the engines for working the branch line trains consumed from 16½ to

35½ lbs. per mile, varying of course with the size of the engine employed to do the work, the smallest engines invariably consuming the smallest quantity of fuel for the same work done. The average consumption of coke during the half-year ending 4th July, 1849, was 31½ lbs. per mile for passenger engines and 47¾ lbs. per mile for goods engines.

"These returns refer to a stock of about 200 engines, and a length of line of about 310 miles."

From these statements it appears that the prevalent notions of the necessity for heavy engines and long trains is without foundation. Could returns be procured from other lines it would be a great advantage to the general railway body.

Having now gone through the general examination of the mechanical and commercial conditions on which the prosperity of railways must be based, it is desirable to ascertain whether all has been done, that may be done, in fostering and creating traffic.

When Mr. Rowland Hill first procured for the public the great advantages of cheap postage, it by no means followed that they would take advantage of it. They had to be trained to the irksome task of writing letters—no trifling matter. Even so the public have to be brought to use the railway when it has been made. But the mode of conducting railways has too commonly been a disregard of the public, against the interest of the shareholders. Their fares have been raised, and the times of trains altered, occasionally with much caprice. A disposition has of late prevailed to diminish the number of trains as a means of lessening expense. But clearly this must be a means also of lessening traffic. In well-constructed trains, the only extra expense of many over few, would be drivers' and stokers' wages. And, with light machinery, speed—that important element to all—rich who spend money, and poor who earn money—speed may be kept up cheaply, without materially increasing the quantity of stock, in many cases actually reducing the quantity. *Frequent fast* trains, are the equivalent of few trains and slow as regards amount of stock, with a great preponderating balance in favour of the public and the dividend.

How to force this conviction on over-cautious Directors, hampered, too, with monster engines, is the difficulty. One leading characteristic of railway men is—the desire to be free from responsibility. A large brain, a strong hand, and an iron will, is ever requisite for onward movement, and it is only men of this stamp who are willing to take responsibility. Coercion only, can operate with men of the other stamp. They will invariably prefer little traffic and high fares, to large traffic and low fares. A railway paying ten per cent. goes on with languor by virtue of a

monopoly. Competition starts, and the languor grows into energy, but misdirected. The money which clear brains would have appropiated to the improvement of their physical means—mechanical and commercial arrangements, with a view to lower their fares, and yet maintain their dividend—is wasted in absurd parliamentary contests, trying to "hedge in the cuckoo" of monopoly. Nothing more absurd than this can well be imagined. They have in their favour the good-will of their established trade, their experience, and other circumstances; in short, all that constitutes the prosperity of every large mercantile firm, and they neglect the cultivation of these advantages, and pay away their "oyster" to "masters of tongue fence," keeping a shell to themselves, with the other for their opponent; or if they gain the two shells, they have but rendered themselves more pervious to the attacks of some new and vigorous opponent at a future time.

For, if a railway has cost £50,000 per mile, the intrinsic cost of which ought only to be £10,000, to accomplish the end sought, viz., the transit of a given amount of passengers and goods, it it is clearly impossible that the owners of such a line, should reap more than the average profit due to a line of £10,000 per mile, taking into account the circumstances of risk—of capital wanting employment—of raw materials ready for use—and of labour crying out for employment. The share market does practically regulate this, writing off in the quotations, the amount of wasted capital, and as much more as may be represented by any inefficient management.

Taking all the circumstances into consideration, the probability is, that many of the great amalgamations will be at no distant period reduced to about two per cent. on their nominal capital, by the very inertia induced by their huge bulk. Monster machines of this class do not work well—individual energy cannot be brought to bear upon them. But if the original lines could be brought under proper management, there is little doubt that they might be made to yield six or seven per cent. on their nominal capital, with all their sins upon their heads. Lines *now* made on thoroughly good principles, and with the traffic of the Eastern Counties or London and North Western to work on, would pay twenty per cent. at this time, and would of course give such a stimulus to railway enterprise that lines would too rapidly multiply; and therefore their proprietors would be wise at the outset to apply their earnings to paying off their borrowed capital, and then reduce their expenditure to the lowest, and be content with such a moderate dividend as to disappoint cupidity.

It may seem a paradox, but the safest railways to invest in would be those bordered through their whole length by a high-

way. In such cases houses, farms, and factories would rapidly border them, because the highway would be the means of communicating with them, and, at the same time, the security against extortionate fares or capricious interference with public convenience. The stage-coach, the omnibus, and the private conveyance would be a security against too high prices, but at the same time would be utterly unable to compete with the proprietors of rails and steam. Railway owners must, in such cases, keep pace with the times, and eschew laziness and all careless modes of transacting their business. A railway, unprovided with easy access, may be surrounded by houses yielding it no service. All railways in the outskirts of towns, or passing through towns, should be conducted on the omnibus principle, of very light and frequent trains, with stoppages every quarter of a mile. The greatest distance for a passenger to walk along the line would be 220 yards. The time will come when all future streets will be made of width sufficient to allow of a railway in the centre, while the side portions are kept for highways. Precisely thus is the North Woolwich line constructed, and the Land Company who have purchased the land, and are building at its junction with the river, will make but a sorry speculation of it, unless they arrange with the Eastern Counties Railway to run quarter-hour trains, or provide a line of their own so to do. The parallel highway may help them, but it is the rail that must impart the permanent value to the property.*

The original cities and settlements of mankind are found along the banks of rivers, as being the best adapted to their wants during the rude state of the arts. There is usually found the best meadow land; there is found water for transit purposes, and for the purpose of turning mills, for grinding and fulling, and for tan-pits and dye-houses. The valley of the river also forms the level for the highway. But to set against all these conveniences, the sites are usually unhealthy, and as population increases, the stream becomes a filthy open sewer.

With the railroad—the artificial level—all this may be changed. With the water main, the gas main, and the sewer, laid along that level, houses and farms become practicable. Irrigation and manure are available through the whole extent. With the farms on the railway line. and the markets at the terminal and other stations, the reduction of expense in transit would be carried to its maximum. So long as a few miles of horse transit to a railway, and a few miles from the railway, shall be needful, the railway will be of comparatively little use; the expense of double trains, and loading and unloading, will destroy the profit.

* See page 76.

It is this consideration that renders it imperative to devise some means whereby farms in general may be connected with railways, and this opens up the general question of turnpike roads, highways, and parish roads.

According to the Parliamentary Report for the year 1847, there exist 22,324 miles of turnpike roads in England and Wales, about 20,000 being in England alone.

The total income from these English roads was £1,242,393 6s. 8d., or about £62 per mile.

The total expenditure on these English roads was £1,256,056 4s. 7d., exceeding the income by £13,662 17s. 11d.

The mortgage debts £6,262,998 17s. 2d., or about £313 per mile.

The unpaid interest £1,467,238 17s. 11d.

The total debts £7,873,252 6s. 5d., or about £394 per mile.

MAINTENANCE OF WAY.

Manual labour	£299,499
Teams and carriages	126,751
Materials, land, and drainage	192,255
Tradesmen's bills	46,085
Total ..	£664,580

or about £33 per mile.

What the highways and parish roads amount to in mileage, no parliamentary data are yet given, but they must far exceed the turnpikes in amount.

Now, if we can imagine our whole system of railroads, commencing with the land purchased, the road ballasted and solidified, the bridges and works erected, the stations prepared and needing only water-tanks, the population existing along the line, and all the cross-roads and branches ready prepared, and all this for £400 per mile; and that on this road so prepared, a single line of rails were laid at a cost, including rolling stock, of £3,000 per mile, or £3,400 total, adapted to the transit of 2,000 passengers per diem, we may imagine what is practicable now with the highways, and what will be found ultimately practicable in all private roads and highways.

The first objection that will be made to this proposition is, the rendering the roads impracticable for other purposes.

In answer to this, the proposition is to insert the rails in longitudinal timbers, the whole being bedded to the level of the road, so that they will not prevent the occasional transit over them of carts and wagons, any more than the existing level

crossings of railways or tramways. Supposing the roads to be of sufficient width, the best position of the rails would be the centre; and if we suppose the present railways to be bordered with highways on each side—turning out when required, we should have a similar result. Even at the towns, and through them, if the streets were wide enough, it would be better not to go round, as is the case in the American towns at present; so that we have examples for those who will not believe till they see, and will not put in practice anything till they do believe—the class of people who would be Chinese, were there no "outside barbarians" to stir them with new matter.

But in old towns where the streets are narrow, crooked, and hilly, the road must go round by the back by a turn out. The inevitable result of this must be, that the back street would become the main street. Thus, in most roads the rail would be in the middle, but in many it would occupy one side. The minor difficulties of fixing water-tanks so as to supply engines in the middle of the road, would be very trifling. The existing sign-posts indicate the means sufficiently.

Difficulties may occur occasionally in crossings being objectionable on the level, but in such cases it is not difficult to span the way with bridges. It must be borne in mind that the subject is always treated with reference to light carriages and engines; and when it is considered that for many years an incline of one in thirty-seven, three miles in length, has been worked by the ordinary heavy trains, there can be no difficulty in imagining that the ordinary highway gradient—the Telford gradient of one in thirty—can easily be worked by the light trains, so as to keep the approaches to bridges short.

There will be another objection raised—that in order to surmount the gradients of highways, slow moving engines will be required, which will be unfit for fast running. This difficulty is also capable of easy solution. A five feet driving-wheel is required for great speeds, but as increase of speed is loss of power, and increase of power is loss of speed, it follows that the five feet on the level should be reduced to three feet or two feet on the incline. This may be accomplished by having two peripheries on the driving-wheels, just as varying diameters are applied to lathes and other machinery, to increase or diminish the speed. Thus, on the level, the ordinary periphery suffices, and on the incline a pair of wider rails must be laid down to take the diminished diameter, such rails being proportionately raised above the surface.

Another objection will be that rails laid on highways will be

* The Lickey Incline, on the Birmingham and Gloucester Railway.

subject to various damages from accidents. Heavy wagons may damage the rails, by wilful violence, and the way may be obstructed purposely, or by stones rolling into the grooves left for the flanges.

In answer to this, we may assume at the outset, that such rails will not be laid down without two preliminaries, the desire of the road creditors and managers, and also those whose property it passes through, and an Act of Parliament to sanction it. There cannot be much doubt that the road creditors will be willing; for they want tolls—interest for their money. And the same class of persons who now break stones on the roads would have to keep them clean—viz., the paupers. Of accidents there would be little risk from getting off the rails, because the railway would be light, and the rail joints would be continuous, with a hard road on the same level. With regard to heavy wagons being used wantonly to damage the rails, remedies would be provided for that; but the fact would be, that no heavy wagons would be used, when once a railway existed—they would not pay.

Another objection would be, that the engines would frighten horses. This might be occasionally, but certainly not more than advertising vans. But horses will cease to be frightened as time goes on. Even now it is the practice of horse-dealers to train horses to engines as to stand any other fire. The writer lays very little stress on this objection, because it is well known that Mr. Walter Hancock did run a steam coach for four successive months, from the Bank to Paddington, along the City-road and up the steep Islington hill, without frightening horses. Another objection is, that it would be dangerous to run at great speeds on the highways, unless certain provisions were made to keep them clear. This objection has some force; but it is not proposed at the outset to use greater speed than the stages—viz., ten miles per hour; and if it be found desirable then to increase the speed, it will be easy to fence off the rails as an ordinary railway. And it is probable that the gradients of 1 in 30 will gradually be reduced to 1 in 50.

It is possible that railway owners might regard this as an unfair interference with their business, but that could not weigh with the legislature, if the plan were lucrative and desirable to the owners of the property on the roadsides. The railways at present very imperfectly fulfil the wants of those who dwell half a mile from the stations. This is remarkably shown by the fact of the number of omnibuses on the Commercial-road, with the Blackwall Railway in close proximity. The reason is, that the fares are the same by omnibus as the rail, and omnibuses are nearest to the houses. Making a railway for the omnibuses to run on, would not affect the Blackwall Rail or its customers. *Before all things* it is essential to the prosperity of a town railway

that it should have stations every quarter of a mile, and that if possible five minute trains should be run. Only thus can the omnibuses be run off the road in the proximity, and driven further off to get a living.

Thus a rail laid from the north side of Waterloo Bridge to Clapham Common along the turnpike-road, would interfere only with the omnibuses and not with the South-Western Railway, which would retain its legitimate customers, being near it. But the property along the road would be very greatly benefitted if a steam omnibus for one hundred passengers, at ten miles per hour, were constantly traversing it.* And it would perhaps eventually serve as a feeder to convey passengers direct from Waterloo Bridge, Strand side, to the Clapham station.

It would do more than this. It would force on the directors, the necessity, and, at the same time, teach the practice of cultivating traffic of their own, by seeking to bring customers to settle along their line; making a law, unalterable as that of the Medes and Persians, against rise of fares or change of trains to such settlers. They would gradually find that as they did not make their line through a street, the next thing is to make a street to their line.

To accomplish this, the railway companies must ultimately go to Parliament to get abrogated the unjust law which deters them from buying land from individuals for their corporate use. It is quite within the scope of probability to imagine that the time will come when the railway will be the minor consideration, and the building and farm property the major. The Strand and Holborn are not valuable because they are public roads, but because they are roads giving access to much valuable property along their sides.

It is quite certain that from the time the first road shall be shewn to be practicable, the whole of the main roads in the neighbourhood of London will be laid down with rails. The saving in "maintenance of way," would be economy—for the average £33 per mile of the turnpike roads must be very largely increased in the environs of the metropolis by the large traffic.

Railway companies, by all means in their power, endeavour to "hedge in the cuckoo" of monopoly. This is quite fruitless. Their only practicable course is to diminish expenses and to increase revenue, by increased travelling.

Of the value of an alliance between highways or turnpike-roads and railways, some idea may be formed by calculating the difference between two thousand pounds per mile laid out on the highway to connect Nine Elms with London Bridge station, and the sum actually expended to get from Nine Elms to the

* Such as the "Fair Field," carrying 130 passengers for 3½d. per mile, as verified in practice.

Waterloo Road, half way to London Bridge, only substituting one inconvenient terminus for another.

It is the interest of so many persons, householders, landholders, farmers and others, to bring about this change, that it cannot be put off longer than till the practical demonstration shall have taken place in a sample line of road. Most new things, till done, are regarded as Utopian and impracticable.

Had the perception of the practical importance of this proposition dawned on the minds of railway managements, the expense of the costly branch lines that have diminished their dividends, might have been avoided, and lines of way skirting the dwellings of the population might have been attained at a very low cost. Whenever a highway-bridge, or turnpike-road, or occupation-bridge, crosses a line of railway, there is the point for a junction, which for light trains might generally be accomplished with very little expense in forming the gradient.

Now, supposing such junctions formed, and that rails be laid down on the roads leading to the town, direct railway wagon communication is obtained. From these towns the parish roads diverge, and rails laid on them might be carried direct into the farmyard. Here, then, we have the produce at one end of the line, and the metropolis or other town at the other end. Under such circumstances, the farmer's carts and wagons would be put out of use, and the light locomotive would be standing in his yard, having brought him a freight of coals, or stone, or earth, or manure, in exchange for his wheat or vegetables.

From this farmyard, lines of moveable rails would be found well adapted to take the wagon and manure by horse-trucks to the centre of each field; or a farm locomotive might be established thereon—a preparation not for ploughing, but for doing the same kind of work better by harrowing; or it might be used to pump water up, to drain away, or to pour over the fields in irrigation; or to inject gaseous manure, or heat, or both combined, beneath the surface of the land for the sake of improved produce. With a small portable saw-bench and morticing machine ready to connect to the engine, the farmer might, with the rude skill of his own farm-labourers, construct from time to time all the wood-work he might require, as is the common practice among farmers in the United States.

It is difficult to estimate the importance of carrying *coals* by rail direct on to farms. From that time the farm will take rank with the factory in its labour-saving processes, and the production of food will be so cheapened as to put to rest for ever the fear of foreign competition. Without cheap coal, farm operations can *but be very* imperfect.*

* See page 76.

In the working of railways economically, the American practice of having but one class, like an omnibus, is a great advantage; because the dead weight is lessened, and there is one kind of surplus weight instead of three or four kinds represented by the English four classes. Vacant places must infallibly multiply in proportion to the division of classes; but constituted as England is by the various habits of society, it would be very difficult to imagine one class. It is not the question of poor and rich, but of education and refinement against coarse manners. The poor man may be the refined man, and the rich man the coarse, but in no case can they mingle, more than oil and water. Yet it is probable that two classes could, with good arrangements, be made to answer every purpose, with increased economy, on the improved plans.

Travellers may be divided into two generic classes—isolated and gregarious. By the isolated, separate small apartments are desired with as small numbers as possible. The desire of isolation may arise from pride and *hauteur*, or from shyness, or from habits of reflection not suited to a crowd; but, from whatever cause arising, the isolation requires more space and weight, and the fares must rise in proportion. Private apartments at the hotel are more costly than the coffee-room—the separate meal than the *table d'hôte* Therefore the gregarious traveller who desires the saloon, occupying less space and dead weight, ought to pay proportionately less. It will be found in practice that the isolated are but few in number; and therefore, as a rule, the saloon form of carriage is the best adapted for economy, both for the company and the public. And it is not even comfort that is desired by the general public so much as cheapness. Many gentlemen even would prefer the third class to the first were it not for the company. Hard boards would not deter them, but the garments of working people would. In the old stage coaches gentlemen hardly ever rode inside, and the outside fares were all alike; but there was a sort of tacit understanding that the precincts of the driver in front were reserved for the gentlemen, and the precincts of the guard behind for the rougher classes.

The introduction of third-class carriages has involved a difficulty. It is clear that the fares generally are higher than the public can or will pay, except occasionally, and when they must travel they do it economically. Directors wish to drive them into first-class by making the second-class hard and uncomfortable, and the result is they go into the third-class. But if the first-class were economically built, similar to London omnibuses in their linings, and the second-class only wood-lined, and the difference in the fares only proportioned to space and dead weight, the first-class would fill, from the fact of the second-class

being the resort of all the economic classes, poor as well as rich. It may be objected that parliament dictates a cheap penny a mile train which obliges the use of third-class. The answer to this is, that as time goes on, a penny a mile will probably be the maximum of first-class, and three-farthings per mile that of second-class.

There is yet another important matter to be considered. As railways are not likely to be all amalgamated together, tolls must continue to exist for the transit of each other's carriages and wagons over their respective lines. On the highways, tolls are chargeable in proportion to the destroying powers of the vehicles. On railways the destroying power of the vehicles will vary from the sledge up to the roller, but the charges are all alike. Time will determine some form better than all others for carriages and wagons; but this can only be the result of further experience. But the chief principle will be to attain the greatest width and length in the carriages and wagons, with the smallest number of wheels consistent with engineering capability. In proportion as carriages and wagons are inferior to the highest standard, so should be the rise in the amount of tolls. But this also involves another consideration—the condition of the railway; for it seems an unfair thing to exact good stock on the one side, and on the other side to furnish a bad road to destroy it. Good brains and inflexible justice will be requisite in the men who are to sit in judgment on these things.

This brings on the question as to who are to be the eventual managers of railways. All past experience points to individual management, with a board of control for emergencies, and that board of control held secure by their pecuniary stake in the concern. Thus do joint-stock banks thrive, when well-paid energy—the payment rising with the exertion—is at the helm. Thus do joint-stock banks fail, when they choose the wrong men, and the board of control is lax in the exercise of its powers.

The manager of a railway must be a man of unusual skill and enterprise, and tolerably versed in human character and the general tendency of circumstances to give direction to enterprise; beyond this he should have the common sense skill to extract the kernels from the engineering shells, cracking and throwing away the empty nuts. For the question of details working into the general, he must take the brains of others, his own logical brain enabling him to detect the specious fallacies. Such a man —honest and well paid, and firm in his position, irremoveable save by his own choice, so long as his duty is performed—would rapidly place a railway in the position its circumstances entitle it to. James Pim and his coadjutors on the Dublin and Kingston line were men of this stamp. They had a railway that paid

nothing—that appeared the most hopeless of all lines; but to their vision, looking into the "beyond," there was abundance of hope for well-judged exertion. They contrived to get a few houses built on a barren sand-beach; they gave inducements to others to build; they kept faith with the public in reducing fares, and increasing accommodation by frequent trains adapted to their objects—and the line was made to pay ten per cent. "What man *has* done man *may* do, even if he can do no more." It will perhaps be asked, where are such men to be found for the mass of railways? The answer is, everywhere; but being men of self-respect, they are not likely to be at the every-day will of those who lack self-respect. The "examiners" of the India House are of this class of men, stripping away rubbish, and verbiage, and sinister matter of all kinds from the subjects passing in review before them, and putting them in a form for common-sense directors to judge thereon.

Having now gone through the various points connected with the prosperity of existing railways, and the advantages of their intimate connexion with those yet to be made, it will be desirable to give the essential points in a

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8. That the maximum weight on the wheel tyres of the engines and carriages should be considerably within the limit tending to produce deflection or abrasion of the rails, or crushing of the sleepers or substructure, or the treading out of the tyres. Neglect of this causes enormous waste of steam power.

9. That the construction of the engine should be so arranged as to keep the centre of gravity low, and the base extended, in order to prevent mischievous and dangerous oscillation.

10. That the carriages and the wagons should be made as long and as wide as the curves and the width of the railway will permit, in order to prevent oscillation, and to economise space, material, and locomotive power in working.

11. That each carriage or wagon should maintain steadiness by its length, without trammeling the wheels, which should be free to move laterally, to suit the curves or inequalities of the rails, and avoid friction.

12. That the wheel tyres should be made of dense iron or of steel, so as not to be subject to wear, and that they should be kept as light as may be consistent with strength, in order to diminish centrifugal action. That the section of the tyres should be such as to permit their application to the wheels by pressure, without heating and cooling, and that the fastenings should not require the piercing of holes through the tread of the tyre, which is a source of great risk. That the wheels should be solid discs of timber or of plate iron, in order a all times to preserve a true circular form, and prevent the fanning action produced by open spokes at high speeds, which helps to waste steam power and retard the train.

13. That the wheels should be free to revolve on the axle, and the axle in the boxes, permitting four movements, thus ensuring the minimum of friction, and diminishing the chance of heating. That the lubrication of the axles in the boxes should be ensured by their revolving in a bath of grease or oil, in constant contact with the lower side.

14. That the springs should be thoroughly flexible and elastic, to prevent all blows or shocks between the carriages and the rails; and that the wheels under each carriage should be sufficiently numerous to prevent any injurious oscillation from acting on a single spring.

15. That the breaks applied to retard the carriages and trains should not so act on the wheels, as to make the wheels sledge or slide on the rails, but that the retarding force necessary to absorb the momentum should be produced by friction between the breaks and the rails directly, thus to prevent the rails from being destroyed at the joints and driven out of the chairs or at-

tachments. Stations should be on elevations, to facilitate starting with little steam pressure, and stopping with little use of the breaks.

16. That every separate carriage and wagon should be provided with traction and buffer springs to prevent snatches and concussions in starting and stopping.

17. That trains ought never to be increased in the number of carriages or wagons, so as to require enormous traction and buffer springs.

18. That the whole of the rolling structures should be as light as may be consistent with strength.

19. That no carriage or wagon should have a greater load on a pair of wheels than is placed on the driving wheels of the engine.

20. That tank engines of very large size, used without tenders for fuel and water, should not be permitted, being more mischievous to the road than the tender engines. The tender was originally a contrivance to relieve small engines of their weight. To add the weight to engines already too heavy, is a most wasteful contrivance.

Commercial Requirements.

1. The more frequent the trains the better the public will be served.

2. Light engines and trains, *i. e.*, small engines and large carriages, can be worked more economically than larger engines and long trains.

3. The same principle applies to light goods, viz., frequent despatches and fast travelling, precisely as the town-carriers now work their traffic.

4. All kind of man-handling of goods wagons is wasteful. Long and large wagons should be drawn by engine power into stations under sheds, with alternate lines of rails and ordinary highways, and discharged by cranes like canal boats. Short wagons, man-handled, are very expensive railway stock.*

5. Short lines in the environs of towns, should be worked by

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* In confirmation of this, an eminent engineer informs the writer that there is at this time an arbitration pending between two railway companies, who have "joined issue" in the North Loch of Edinburgh Castle, and one company claims damages from the other to the tune of £150,000, for having, contrary to agreement, provided turntables in place of sidings at the goods station, thus entailing on them for ever a heavy annual cost in man-handling.

The invention of the turntable as a contrivance to economise space has been a most insidious enemy to railway prosperity. It is a process of paying a ruinous interest in daily expenses for ever, to avoid a present outlay. The cost of man-handling wagons is probably greater than that of the transit.

small five minutes' trains, like omnibusses. Passengers do not object to wait for the next train when the trains are in quick succession,

6. That highways may, in many cases, be advantageously laid down with rails for horse or light steam transit, on the same gauge, to communicate with branches or main lines of railway.

7. That landowners may, with great advantage, construct cheap lines through their own estates, on which to place their farms.

8. That in many cases it would be for their advantage to *give* the land needful to construct lines of railway.

9. That when the traffic of both goods and passengers is desired in maximum, the true mode is to make two lines for passengers and fast traffic, and a third line for goods and slow traffic, and to provide also a parallel line of highway close to it. The North Woolwich Branch of the Eastern Counties line is a sample of this. Being obliged, by Act of Parliament, to make a parallel highway, the directors are precluded from charging too high prices, and streets of houses are gradually accumulating. At no great distance of time this line will be a railway through a town on the same level. Future towns will be thus constructed.

10. For the accommodation of the wealthier classes, willing to pay for speed and accommodation, it would be desirable to institute *Subscription Trains* of great lightness and speed, carrying, say seventy to one hundred first-class passengers, with light luggage, and accommodation for a few servants.

A train of this kind, consisting of an engine and tender break van, with accommodation for fourteen servants and luggage, and a light first-class for sixty-four passengers, would travel at fifty miles per hour without stopping.

A train of this kind might be run from London to Liverpool, and *vice versâ*, in five hours, starting at 7 A.M. and arriving at noon; starting again at 6 P.M. and arriving at 11, would leave six hours interval in London or Liverpool for business. This, with a carriage fitted for reading and writing, and with not more than five stoppages to water and coke, and without loss of time in ticket collection, would surely be a great advantage to the higher order of the mercantile community.

Maintenance of way with such light weights would be practically *nil*.

Large roomy seats with folding reading-desks are contemplated in this arrangement. Eight separate bodies to the carriage.

11. Though it is probable that ultimately most lines will be worked by the principle of contract, still it is desirable that no such contracts should be entered into under existing circumstances, and especially for long periods. Shareholders have been

driven into a panic by results different from their expectations unreasonably raised, and now they rush into the other extreme and waste their property, in the mistaken notion of decreasing their expenses. It is quite clear that contractors will not work without profit, if they mean fair dealing; and for companies to resort to contractors is simply a proclamation of want of faith in the intellect or morality of their officers. They have chosen badly, and think that they will be infallible in their choice of contractors, or rather in their lottery; for the auction system does not usually bring the choicest goods into the market. They may depend on it that the sound contractors will either have good profits, or some means of getting rid of the contract when the stock is worked out,—and valuations always go against companies.

But there is another thing. Assuming that the present mode of working is costly—in short, twice what it may be reduced to—the company are debarred from any results of improvements. A heavy contract, based on existing expenditure, would make it worth a contractor's while to house and lay up all existing stock, and work with improved stock, and at the end of the term, return the antique rubbish on the company's hands, and with his improved stock, go away to work a rival line.

The assumption of finality in the structure and stock of railways is simply ludicrous, and the companies must work out their own redemption by their own energies, or sell their property at reduced rates to those who can and will.

Contracts imply definiteness; and in all things that can be clearly defined, and are within the scope of individual or private skill and power, companies will do well to go to contract: they will get things best and cheapest. But let them have a dread of the indefinite. A shrewd contractor once remarked to the writer, "I never sign a contract till my lawyer has assured me that I have a loophole."

"Maintenance of way" is an item which companies usually let by contract. There are certain risks attending this, and the contractor puts on a very high insurance for it. But maintenance of way can scarcely be defined; six people will say it is well maintained, six others that it is in very bad order. In fact, it is all relative. The line may be in fine working order for one class of stock, and the contrary for another class.

A matter of opinion cannot be defined; only fixed quantities can be defined, and "permanent way" is as yet only a moving quantity. In the American phrase, embodying the expression of indefiniteness,

"It is about as big as a piece of chalk."

It is of comparatively little use to criticise, unless the criticism

be accompanied with some tangible proposition for remedying the defects so criticised. The writer does not fall into the category of this omission. Those who may visit Fair Field Works, will have an opportunity of inspecting plans that have been devised for remedying the various mechanical defects pointed out.—Many of them are in public use, others are awaiting the perceptions and fiat of railway directors, who, like the Roman Centurion, have power to say, "Go! and he goeth; Come! and he cometh."

Without new inventions, the English nation would lapse into Chinese. There is an old saying, "What man has done, man may do!" But, unless succeeding men do more than preceding men, it will be a thriftless world. Yet is the inventor truly but a small part of the affair. It is the appreciators of the invention who have to put the "image and superscription" upon the uncoined metal, in order that it may go forth to the world, and pass from hand to hand as of recognised value, and which no man may doubt of.

And now to return once more to *the* question—the paramount question of railway extension, by working practicable engines and trains.

It may be that in thickly settled countries, with incessant traffic, massive railways and huge engines may be required; but for countries newly settled, thinly peopled, and slowly emerging from barbarism, it must be clear that the light cheap system must be the best adapted. Australia, Canada, New Zealand, South America, and India, can only acquire a general system of railways on such a plan. Trunk railways may perchance be made with a great outlay of capital, but trunk railways open up a country but very imperfectly. On the adaptability of this system for India, a very practical man, Colonel Grant, of the Bombay Engineers, resident at Poona, speaks in the strongst terms of approbation and goes on to say that—"The heavy English locomotives would necessitate a description of work, and an expense of construction and of working the line, that *must*, with the traffic that India ever can provide, prove fatal to the general adoption of railways as a means of transit in India."*

It is the object of the writer of these pages to be strictly practical; and the fact that he has carried almost the whole of his mechanical views into practice, recognised publicly as beneficial to railways, gives him the right to look forward to future results. It is by slow beginnings that great works are achieved; and thus it is the tendency of railways to increase whenever they are at

* "Bombay Cotton and Indian Railways." By Lieutenant-Colonel C. W. Grant, Bombay Engineers. Longman. London.

first healthily organised. They should not at the outset be saddled with too costly works. The rails well and efficiently laid, and the economic quality of the rolling trains are the chief considerations. Even bridges are but a secondary consideration. It is better to make a railway in separate lengths in a wild country, than to outlay a capital that will not yield return—better to have a cheap ferry than a costly bridge.

On such an economic system the cost of constructing a railway between Cairo and Suez would be reduced to £300,000—an undertaking that individual merchants might embark in, and manage almost as a private speculation; an undertaking that the Americans would long ago have accomplished had Suez lain anywhere in their track.

And viewed thus, the project—to which the *Times* some time back devoted a very able leading article—of getting to India wholly by land, save the two or three water straits, wears an aspect of probability. And no truth is more certain than that the civilization of Algeria and other parts of Africa must depend on railways cheaply made. If it be true that the sands of the Great Desert overlay a huge river of fresh water, it becomes clear that when that water can be raised to the surface by the agency of steam, the mat of vegetation may commence. Working from the coast inland, by the agency of the cheap railway, seems the practical means to accomplish this.

It is a proud distinction for the English nation and their offshoots in the Far West, that they have been the great railway makers of the world. Even Russia could not get her railways, till she had imported American citizens to make them.

And there is much work for England yet to do in railway making, even while her own progress lies in abeyance, because cupidity has taken fright at its own absurd doings, and resolves for a time to do nothing, as a balance for having done badly. It will not even make the railway to Falmouth, the ancient shipping port for the south, and which will again become the shipping port, when the civilising rail shall have restored the balance of advantage which Southampton now possesses.

Opposite to Falmouth, across the Bay of Biscay, lies the Spanish port of Santander, a sea transit of some two to three days' steaming. Twenty miles inland from Santander lies a coal region now becoming a nucleus for Spanish railway enterprise, in the construction of a line to bring that coal to the seaport, and ultimately to carry it coastward and inland. On the opposite side of Spain, bordered by the Mediterranean, there is a short line inland from Barcelona to Mataro; and in the centre of Spain the royal railway from Madrid to Aranjuez, is the commencement

of the route shortly to open, that will ultimately lead to Alicant. The railways as yet made have been constructed on the old costly system, and this is unfavourable to progress; but if new lines be made on the economic plan, at no distant period the Spanish Peninsula will be intersected throughout; and once that all parts become accessible to others, Spain will cease to be a bundle of disunited provinces—of separate clans—and rise to the rank of a great nation. It will be as the birth of a new world to us when this time shall arrive; when the manufactured wealth of England shall be poured into Spain, and the rich produce of the land of the olive and the vine shall come hither in payment for it. "Santiago y Cierra Espana!" was the old war slogan of the Cid, "St. James and Close Spain!"—"Santiago y Abrid Espana!"—should be the motto of the modern chivalry, the riders of the peace-making fire steeds—"St. James and Open Spain!"

Italy also, late the scene of strife and bloodshed, and alas! not yet a nation, has to be railroaded and iron-banded into union. And even now she is once more invaded—not as of old by a Brennus or an Attila—not by armies of fighting Condottieri seeking to plunder industry of its hard earnings; but by hosts of Saxon navvies and contractors—not the free-masons but the free-railers of the world, shut out from their home employment by the false money-changers, who have driven frightened capital into coffers and strong boxes, and now roaming throughout the earth, and competing with each other which shall make transit the cheapest.

Our English railways have received a rude check. People fear them as investments; but as fear is the result of ignorance only, and knowledge will grow, the stagnation of railways can only be temporary. When the light shall shine on them, progress will again be active, and more prosperously than before. Much suffering must meanwhile be undergone, but that is the imperative lot of imperfect humanity.

To conclude. Railways will not attain their maximum prosperity till they shall obtain the *repeal of the inland transit laws*, that are as mischievous to railway prosperity as ever were the "navigation laws" to the shipping interest, or the corn laws to the agricultural interest. There is no valid reason why railway proprietors should not be land-owners, and house-owners, and miners, and quarrymen, along their own line, provided such property be attained by voluntary contract, and with the consent of the shareholders. There is no valid reason why they should not be water companies, and gas companies, and sewage companies, as well as transit companies; for in their artificial levels they are better provided with appliances for these objects than

are other people. Little does the writer heed the cuckoo cry of monopoly that may be raised against such a proposition. All things that require combined effort are the legitimate business of public companies, and in those things which are not their legitimate business, individual energy will always beat them. The *Aguadores* of Madrid, if every individual Gallego or Asturiano poured down from their hills, could not compete with the iron mains now about to cleanse that ill-washed city. The bottomless pitchers of the Danaides were a hopeful task compared with such competition. Yet still more absurd would it be, were a public company of skin-bearing, day-paid water-carriers to enter into competition with the individual Gallegos, who work by the piece. Public companies are not wanted to paint pictures, or to make chairs and tables. They are wanted for the great operations that change the face of Nature, and win a new world from the wilderness.

APPENDIX AND REFERENCE TO PLATES.

Sheet I. represents a light four-wheel locomotive engine, with 9-inch cylinders, and a tank for 250 gallons of water on the same frame. Attached to it by a spring coupling, which permits lateral bending to pass round curves, while preserving vertical stiffness, is a four-wheel Composite Tender, making the whole practically an eight-wheel engine, very safe, steady, and economical. The Composite Tender combines a guard's break-van, a luggage compartment, and a body for fourteen passengers, with a tank beneath the floor for 600 gallons of water. Thus eight wheels accomplish the work usually done by fourteen to sixteen; and, supposing the vehicle used for express purposes as a special in the winter, the passengers may be comfortably warmed from the tank. Empty, the total weight will be about fifteen tons.

Sheet II. represents an eight-wheel composite passenger-carriage for 40 first-class and 64 second-class; total, 104;—or for 20 first-class and 96 second-class; total, 116. Length over buffers, 44 feet. Figures 1 and 2, Sheet III., are two diagrams, one of the above carriage, and the other showing the length in ordinary four-wheel carriages to form an equivalent, being on 16 wheels, 36 first-class and 64 second-class; total, 100;—or 18 first-class and 96 second-class; total 114. Length over buffers, 88 feet.

Fig. 3, Sheet III., represents a double wagon on eight wheels, to carry 16 to 18 tons; length over buffers, 36 feet. Beneath Fig. 4 is a diagram showing the equivalent in three ordinary wagons on twelve wheels; length over buffers, 60 feet. To understand the advantages, the reader must peruse the following statement of "The Economy of Wagon Transit on Railways:"—

THE ECONOMY OF WAGON TRANSIT ON RAILWAYS.

The ordinary modes of constructing wagons for railway transit, involve two serious evils, resulting in destructive wear, and waste of capital in outlay.

1. The ordinary four-wheel wagon does not run straight or steadily unless the train be closely coupled, in which case great surplus friction is involved, and a greatly increased demand for engine power. The wheels traverse laterally to suit their peripheries to the inequalities of the rails, and by the mode of construction the bodies of the wagons move laterally with them. This involves a constant succession of shocks, most mischievous to both wagons and rails, and aggravated by the whole weight of the load. The result is a diagonal pitching movement, to counteract which, each of the four springs must be made sufficiently strong to bear three-fourths of the load, so that, except when the wagon pitches, they cease to be springs at all.

2. In consequence of this unsteadiness and oscillation, it is impracticable to place so large a load on the wagon as its strength is fitted to carry, and the proportion of dead load to available load is much increased. Thus more wagons are required.

By the construction of Adams' patent double wagon on eight wheels, these evils are remedied. The wheels are so arranged that they can traverse laterally, each pair independently, to avoid flange friction on curves or inequalities of the rails, without disturbing the body or causing oscillation, and at the same time enabling a wagon of from 35 to 40 feet in length, to pass round curves of four chains radius.

And in consequence of the numerous points of support, very flexible springs may be used; because there is no oscillation, unduly to oppress any single spring.

The construction of the wagon does not involve unwieldiness, because it is made in two parts to couple rigidly together, and can with facility be removed from the line when required, for repairs or in case of accident.

In consequence of the absence of oscillation arising from increased points of support, the double wagon can be made considerably wider than common, and will carry a far greater load. The two wagons conjoined will carry one-third more than the two separate, precisely as a bundle of sticks tied up form an aggregate strength, greater than the same sticks separately.

The economy of this is evident, for two wagons supply the place of three. The load proposed for these double wagons is 18 tons, and the length occupied in the train is 36 feet, the dead weight being, say eight tons.

These ordinary wagons carrying the same load, would occupy 60 feet length of train with a dead weight of say 12 tons.

When it is considered how much the friction of a train is increased by its length, especially on curves, the economy of this arrangement is still more obvious. The advantages are—

Saving in length of train, landing wharfs, &c., 36 feet against 60 feet, or 24 feet.

Saving in positive dead weight, 8 tons against 12 tons, or 4 tons.

Saving in proportional dead weight to available load, 18 to 8 against 18 to 12.

When it is considered that a town wagon weighing 1½ tons carries 4 tons, it is quite clear that the economy of tare in railway wagons has not yet reached its maximum.

But beyond the direct saving by the use of these improved wagons, their structure by reason of their large floor area, and extreme ease, and entire freedom from oscillation, offers a still wider economy.

Town wagons are made to carry every variety of load—coals, grain, flour, metal, bale goods, crates, hampers, hay, straw, hops, casks, and numerous other commodities.

Railway wagons, on the contrary, are constructed for separate uses, viz. :—

Hopper coal wagons, rarely applied to any other purpose.	Lime wagons.
Common coal wagons.	Goods wagons.
Coke wagons.	Low sided wagons.
Grain wagons.	Cattle wagons.
Ballast wagons.	Sheep wagons.
Timber wagons.	Milk wagons.
	Crate wagons.

Now, it seems quite clear that a very large saving may be made by such a construction of wagon as may be equally well adapted to carry coals, coke, grain, hay, straw, hops, wool, ballast, milk, general goods, cattle, sheep, and pigs. This would prevent the haulage of "empties" and save surplus stock.

The eight-wheel wagon will accomplish this, and moreover, being perfectly steady and easy, it may be provided with spare seats to serve for cheap excursion trains when required, carrying 100 passengers, and saving the companies a large outlay in more costly stock, not applicable to other purposes.

To keep their vehicles in use and few standing idle, is the economical course for a company. Wagons standing exposed over a line suffer more than when running.

The saving in the numbers of wheels by the use of these

wagons arising from their greater capacity would be one-third, *i. e.*, 2,000 wagons would supply the place of 3,000.

And probably the saving by the convertibility of the wagons to various purposes would be equivalent to one-fourth the remainder; so that 1,500 wagons would really supply the place of 3,000.

The proposed construction of the double wagon is as follows :—

Extreme length of each wagon 16 feet, making a total of 32 feet, coupled over ends, and 36 over buffers.

Extreme width 9 feet.

Extreme height from top of floor to top of side rail, upper part open for cattle, 5 feet 9 inches. Extreme centres of wheels when coupled, 25 feet 6 inches. The wheels arranged for lateral traverse of 9 inches. The wagons are fitted with false bottoms, or moveable, for the conveyance of coals, coke, lime, chalk, ballast, or similar cargoes, to be discharged on the hopper principle. After the discharge, the flaps can be folded down and the wagon will be converted into a goods or cattle wagon, for which purpose it is also fitted with foot batons to prevent the cattle from slipping. The cattle would travel as easily as passengers.

Existing railways being very commonly arranged so as to save land at stations by the use of turn-tables, these wagons are arranged to suit such turn-tables, when uncoupled. But wherever the use of turn-tables can be avoided by the use of sidings, discharging the wagons as canal-boats are discharged, a great economy will be attained. It is man-handling versus steam power, where the turn-tables are used; and manual labour absorbs a large portion of the profits. Had carriage and wagon turn-tables never been invented, the traffic of the railways would have been conducted at considerably less cost.

Supposing a railway to be in perfect order, an engine with 14-inch cylinders should be capable of taking twenty of the above double wagons on the level, with a gross load of 520 tons—*i.e.*, 160 tons tare and 360 tons paying weight—the length of train, exclusive of engine, being only 240 yards.

OPINIONS OF THE PRESS ON LIGHT AND FREQUENT TRAINS.

From the "Times" of December 24th, 1849, Money Article.

A circular of Messrs. Adams and Co., of Fair Field Works, Bow, contains some facts and suggestions confirmatory of the belief we recently expressed, that the adoption of frequent light trains on railways, instead of infrequent heavy ones, would be found an important element in those practical reforms from which the revival of railway property must now in a great measure be looked for. Messrs. Adams contend for the employment of light engines, combined with large carriages; and they assert that not only might increased safety and much greater speed thus be obtained, but that a reduction would at the same time be accomplished of 50 per cent. in working expenses, while the maintenance of the permanent way, now estimated at from 50*l.* to 100*l.* per mile, would be reduced, from the fact of the weights not approaching the crushing point, almost to *nil.* Under the system of short light trains instead of long heavy ones, the number of journeys, it is also pointed out, could be greatly augmented, and in this way the increased accommodation to the public would again be attended by a diminution of expense. Smaller stations, shorter platforms, and fewer servants would be required, since, instead of the arrival of confused crowds of passengers at long intervals, there would be a more moderate but continuous traffic throughout the day. Carriages of this description, it appears, are in daily use on the Cork and Bandon line, and at the last half-yearly meeting the report of the engineer was as follows:—

"The performance of the light engines has fully realized my expectations, both in respect to speed and efficiency, as well as in an economical consumption of coke. These engines are found fully capable of conveying a train of 120 passengers (a length of nearly ten miles, of many curves, and with long inclines of 1 in 100) between the two termini of Bandon and Ballinhassig in twenty minutes, including stoppages at the intermediate stations, with the most perfect ease and safety. All the trains, up to the present time, have arrived with punctuality."

Whether there are any difficulties that would prevent the immediate accomplishment of similar results on more extensive and important lines, is a matter to be demonstrated by experience, but that attention must henceforth be directed to the point; and that it will be from something of this kind that the shareholders must mainly hope for revived profits, and the public for increased accommodation and lower fares, can hardly be doubted in the face of the following statement:—

"It appears, by the returns of one of the most important metropolitan railways, embracing upwards of 300 miles of way, that for the week ending May 7, 1849, the greatest number of passengers in any

main line train at one time was 231, and the smallest number was 7. The greatest number on any branch line was 82, and the smallest number was 3. But the most startling statement is yet to follow. It appears that on the total lines of the same railway during the year 1847 there were carried 42,644 tons of passengers taken as weight, while the weight of the engines and carriages required to convey them was an aggregate of 1,112,570 tons, or upwards of 26 tons of dead load to 1 ton of paying load. Such a statement as this furnishes abundant reason why railways do not remunerate shareholders for their outlay."

From the "Times," January 25th, 1850, Money Article.

A pamphlet, just published, entitled—the "Iron Ways," will be read with satisfaction by proprietors of railway shares, for its hopeful anticipations of what may be effected towards a restoration of profits, by the adoption of light and frequent trains. It also contains a number of suggestions on the general development of traffic, which, in point of ingenuity and completeness, as well as in the faith they exhibit, in the extent to which the public would avail themselves of increased facilities, resemble the original Post-office plans of Mr. Rowland Hill.

From the "Spectator," February 9th, 1850.

REDEMPTION OF THE RAILWAY SYSTEM.

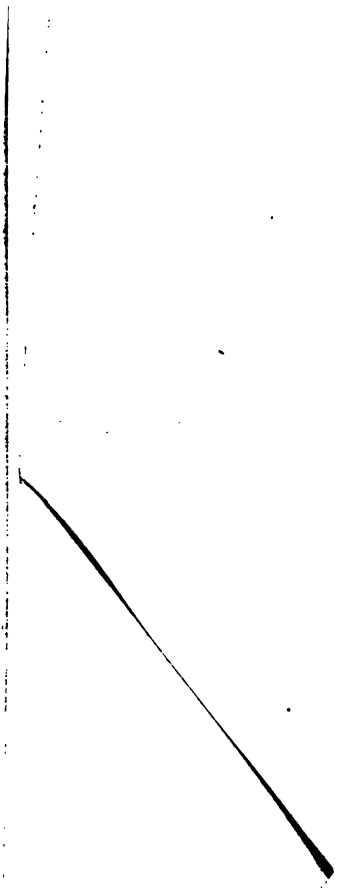
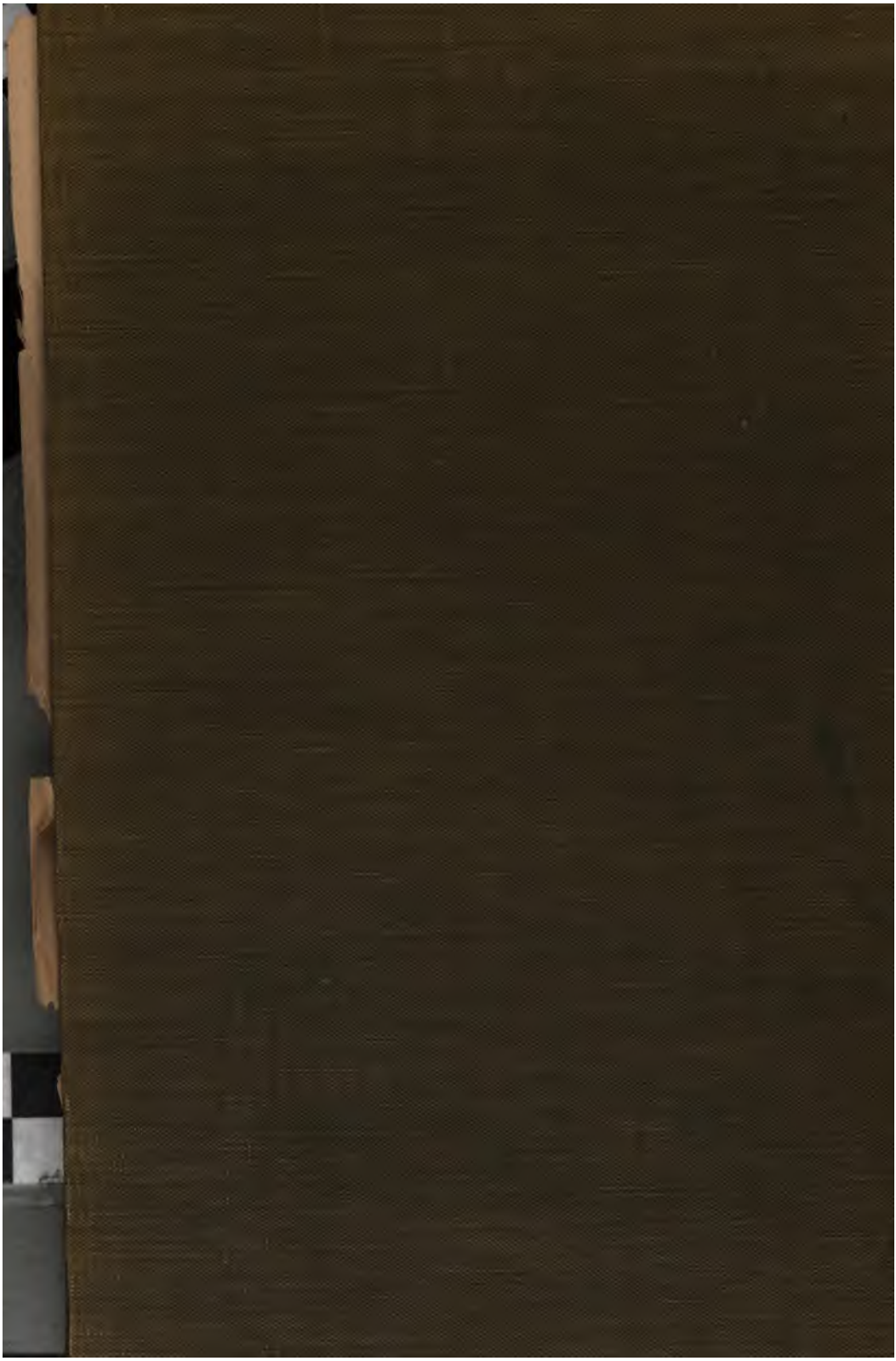
Dislike to be taught is a trait of the English character; insomuch that your true-born Englishman positively refuses to learn anew of any one who can teach him at first hand, and will only learn of "experience." In a scientific matter he will not learn from the veriest Newton of the science, still less from any foreign Liebig or Humboldt; but will go on trying the unscientific blunder, till repeated failure jostles him into the right course. This he calls "not being theoretical," and "being practical." Thus the stout British farmer takes any scientific examination of his state as an insult; the promoters of wood pavement obstinately refused to try any plan for correcting the slippery texture of the wooden surface; and the railway world insists on keeping an ill-adjusted heavy traffic which crushes both permanent way and dividends. Those who desire to see the opposite view, may consult a paper in the current number of the *Westminster Review*, since republished in the form of a shilling pamphlet.

The author shows how the railway world can be rescued from its difficulties, and how the extension of a more manageable railway system, by its minuter ramifications into the very farms, would reconcile farming with free trade; as it would make transit easy both for produce and locomotive farming apparatus, and would thus bring a full manufacturing power and activity into the heart of agriculture. But although the view is put forth by a practical man, its reasoning is so clear, and its method of attaining the proposed end is so direct, that railway folks will pronounce it "unpractical"—not sufficiently mixed

up with the necessary elements of failure—*too* free from bad engineering and Hudsonism. Your true-born Englishmen is so little of a perfectibilitarian that he prefers that which is imperfect ; he likes to begin with the bad, and proceed to the better ; and he has no faith whatever in the best—especially by any direct route. But for his Protestant creed, he would no doubt prefer the idea of going to heaven by way of purgatory; it would be most practical.

So broad, and yet carried out into details, the view propounded in *The Iron Ways*, forbids a compressed reflex in our crowded space. The main elements are these. The use of heavy engines, carriages that are proportionately heavier, and trains still heavier, beget cost in the waste of fuel and apparatus for locomotion, and also in the destructive crushing effect which it has on the permanent works of a railway, especially on the rails and bridges. Attack the evil then in its procreant nest—grapple with the weight of the rolling stock. In lieu of heavy engines, substitute light ones ; in lieu of heavier carriages, lighter ; in lieu of indefinitely lengthened trains, trains limited.

The plan thus suggested is worked out in a manner that seems to us to be in principle quite satisfactory. But it has a merit beyond that of suggesting what would be a good system in itself—it suggests a method by which the railway interest may escape from its present difficulties. In spite of its cumbrous structure in rolling and permanent stock, the railway interest is notoriously threatened with two serious causes of expense. The public will demand a continued extension of the minor ramifications ; and if that be not supplied by one company for any given district, it will by another company ; and so the railway interests will be *forced* into the losing system of "extension-lines," or will be obliged to forego some part of a productive traffic. But the lighter style of traffic would materially alter the character and cost of these extension-works ; until, indeed, by keeping a uniform gauge—like the maximum for the wheels of carriages on highways — the railway might fine off to meet the moveable lines branching into every field. Again, defective construction already threatens a break-up of several railways, with the alternative of immense outlay or deferred cost for reconstruction, accompanied by horrible disasters : the plan of light traffic reconciles safety with a further postponement of reconstruction—especially for those bridges that are beginning to fall in far too often. This will give time to provide capital, and to effect the greatest possible improvements in the modes of construction for permanent ways and bridges

Into the farming branch of the subject we will not enter. But it speaks for itself. The cotton factory is, as they say in Scotland, "self-contained," and the work can all be concentrated round the engine ; in the farm, the engine must go to its work. The engine, then, must be feeble, or being weighty, it must be provided with stable ways underneath it ; so that steam farming implies a net-work of private railways.

"Will you destroy our fields and green lanes ?" cries the landscape-painter and the lover of nature ; "Will you convert green England